An Atlas of Glass-Ionomer Cements

A Clinician's Guide

Third Edition

Graham J Mount, AM
BDS, DDSc, FRACDS, FICD, FADI

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Foreword

The third edition of *An Atlas of Glass-Ionomer Cements* by Graham Mount will remain a tribute to his continuing effort to encourage the dental profession to forsake any prejudices and recognize that glass-ionomer cements and composites both have a role to play in restorative dentistry and complement each other. The controversy over whether to use resin dentine bonding agents or glass-ionomer bases is but one example, and this book covers the subject so well, offering the general practitioner sound practical advice on selection of materials and the logic for doing so. Perhaps the words of Sir Norman Bennett whose name is still associated with 'The Bennett Shift' ring true today: in a paper he gave to Guy's Hospital in 1907 he said, 'I do not know to what extent my ideas are new and certainly make no claim of the kind. I am concerned chiefly with their merits and demerits, and their usefulness to a profession so fully imbued with the desire to learn and withal so difficult to convince.' Graham Mount has done more to convince the profession of the benefits of glass-ionomer technology than any other clinician, and he has the ability to convey his learning both in the clinic and in his understanding of the chemistry of these complex materials. Although in his preface he claims that this is his last contribution, one wonders whether the James Bond title *'Never Say Never Again'* will not ring true!

This new edition is his most comprehensive and expands into the biological potential of glass-ionomers in both the medical and the dental field. The chapter by Hien Ngo is worthy of close attention. In the light of current knowledge the role of resin-modified cements and compomers (polyacid modified composites) is dealt with in greater depth than in the last edition, and Mount draws attention to the over-promotion of light activation where some materials do not exhibit any significant glass-ionomer acid-base reaction and suffer from swelling in water and lack long-term colour stability. The traditional glass-ionomer cement remains dear to his heart, and he shows in his long-term clinical studies that if handled correctly and protected from moisture in the early stages of setting, the final restoration is dimensionally stable, adhesive to dentine and exhibits little colour change. Many long-term colour photographs that reinforce his textual message back up these results.

Minimal intervention cavity designs are receiving more attention and Graham Mount is a true pioneer in this field. He has assiduously spread the word via the international lecture circuit about the great advantages of these fluoride leachable chemically adhesive cements used to restore this type of cavity. His chapter on luting cements also contains much information on the selection of cements, including resin-modified and two paste systems, with a clear explanation of all the various systems. This is a confused area and the chapter will greatly assist the clinician in unraveling some of the mysteries of these newer materials.

With his third edition Graham Mount will leave us with the knowledge that he has gained international respect for his work and done much to enhance the prestige of Australian dentistry.

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Preface

The first edition of this book was published in 1990. The glass-ionomers had been available for just 14 years, and were therefore not widely established. There was, in fact, some degree of scepticism about their value and place in operative dentistry, particularly in the light of the growing wave of enthusiasm for the composite resins, which were not much older. It was these that were regarded as the new wave of dentistry. They were aesthetic, strong, light-activated and, we were told, simple to handle. Some of the advantages of glass-ionomer were recognized, such as the release of fluoride; so there was a move to 'marry' the two materials into one, and a 'light-activated' resin containing glass-ionomer was developed. This led to the second edition in 1994, which was rather hastily written to cover the latest significant development.

In the last seven years there have been substantial changes in our understanding of this group of materials, and it is felt that these changes justify a further edition in an attempt to establish finally their position within this discipline. There is no doubt the glass-ionomers represent a major shift in operative dentistry. Up to this point all restorative materials have been almost completely inert and have offered no positive advantage in the fight against dental caries. The sole exception was silicate cement, which released fluoride and was well known for its short life-span. However, though it washed out regularly at three-year intervals, it was also notable for the fact that the adjacent tooth structure was not carious at that point. You simply cleaned the cavity and replaced the silicate.

From the moment of its conception it was known that glass-ionomer would release fluoride in the same way, and it did not take long to find that it also adhered to tooth structure through an ion-exchange mechanism, which, up to that time, was a mechanism unknown to science. It is now developing a reputation for longevity as well as for imparting a similar degree of resistance to demineralization to adjacent tooth structure. Research over the last seven years has shown that it does far more than just release fluoride and stick to tooth. It is, in fact, a highly complex bioactive material that releases other ions as well and, what is more, all of these ions can play a part in the remineralization, or healing, of tooth structure.

Over the last thirty to forty years there has been a considerable amount of time and energy expended on the demineralization/remineralization cycle that is now recognized to constitute the essence of caries. The role of fluoride became better understood, and the potential for actually healing an early lesion was realized. However, one essential part of ensuring effective remineralization was the need to seal the lesion completely from further bacterial contamination. Glass-ionomer fulfils this need and at the same time provides additional free ions that can become involved in the healing process.

Caries is, of course, a bacterial disease, and elimination is dependent upon reduction of the infection. No restorative material can be resistant to further carious attack, and it must be acknowledged that so-called 'recurrent caries' is simply a continuation or a reinfection of the same problem. However, the use of a bioactive, fully adhesive material that is capable of assisting healing has to be an advantage. All materials have their limitations, and it is unlikely there will ever be a universal restorative for all situations. But it is apparent at this time that glass-ionomer should be regarded as the universal base for restorative dentistry, either to stand alone or to be laminated and reinforced as required.

Obviously this is not the end of the story. There is much work yet to be carried out to develop a full understanding of the actions of these materials. There are variations to be tested, improvements in physical properties to be developed, other elements to be investigated. It has already been suggested that strontium is highly antibacterial; but its level of action has yet to be determined. Zinc has always been known to assist in healing; but its potential as a part of this system is unknown.

The future for this class of material is hard to measure at this point; but one thing is obvious – it has a future. My contribution will cease at this point, and it is now up to the next generation to pursue this future and see that it does not get lost under the load of marketing of alternative materials.

Acknowledgements

A treatise such as this is not written without a lot of help from a number of people. I begin by thanking all those chairside assistants who assisted me in the compilation over many years of the records and photographs, most of which are mine. My appreciation also to Dr OF Makinson, who has been my mentor and support for as long as I have been involved in research. There has also been a steady supply of undergraduate students at the Dental School, Adelaide University, who have been allocated Vacation Research Scholarships and have carried out projects investigating varying aspects of the glass-ionomers. Most of these scholarships have been funded by the Australian Dental Research Fund, and the profession should be aware of the great benefits that have arisen over many years from the activities of this Fund.

However, the one who has been my greatest inspiration for this edition has been Dr Hien Ngo, a general practitioner here in Adelaide, who is at the same time a gifted researcher. All of Chapter 2 arises from the research and reading that he has carried out in recent years both in his practice and at the Colgate Australia Clinical Dental Research Centre, Adelaide University. He has helped to tie together the work of a lot of other people going back as far as Massler, Fusayama, and Brannstrom in the 1960s and 1970s. The work they accomplished showed the potential for healing of tooth structure; but, in the absence of a bioactive adhesive restorative material, the implementation of the theory was difficult. The advent of the glass-ionomers has opened the way to new methods of dealing with early lesions, and this in turn has the potential for modifying our whole approach to restorative dentistry.

There is considerable research being carried out at this time into the materials themselves, most of it by the manufacturers. There is no doubt that these are early days, with much to be done before they reach their full potential; and the profession is grateful to those who devote so much time to these projects. With the knowledge that these changes are taking place I approached the three Companies who have been responsible for the major developments to date. All three graciously accepted my invitation to comment on the contents of Chapter 1 in particular, and were free with their knowledge and information on newer developments. This means that the contents can be regarded as up to date as at this time – but changes will continue and the reader must be prepared for continuing change.

I am therefore grateful to Mr MJ Williams and Dr K Hirota from the GC Company, Tokyo, to Dr Sumita Mitra from 3M Dental, Minnesota, USA and to Dr R Guggenberger and Dr K-P Stefan from ESPE GmbH, Seefeld, Germany, all of whom have played a part in the accuracy and validity of Chapter 1. I must add my thanks to the people at ESPE GmbH for some of the information on glass-ionomer as a bone substitute in Chapter 2. Dr TF Watson kindly provided Figures 1.30 and 1.31. Dr J McIntyre of Adelaide kindly provided Figures 7.103 and 7.104.

In the final rundown to publication Hien Ngo has helped considerably with advice and directions and updates on the state of science at this time. There have been many changes since I was a student, and keeping pace is not easy. Then my good friend Michael Williams passed his eagle eye over the entire manuscript to make sure I was not being too repetitive or wordy and that the text ran smoothly.

To all I owe a debt of gratitude; but the debt to them is not nearly so big as the one owed to my principal supporter, my best friend and favourite travel companion – my wife – who has stood by me for over 50 years. Long may she reign!

1 Description of glass-ionomers

The glass-ionomer family of materials is one of the most versatile of the acid–base cements, and it has many applications, particularly in dentistry (Wilson & McLean 1988). Within this profession it is useful as a restorative material, a lining material or a base (dentine substitute), a luting cement for crowns and bridges (Knibbs 1988) or a bond between another restorative material and tooth structure. Outside dentistry it has proved useful as a bandage and splint material, a bone cement, a replacement for plaster of Paris in slip casting and a model material. Such applications have been shown to be very versatile, and in recent years they have been subject to considerable development, improvement and diversification, to the extent that, at this time, they are really very different from the original ASPA that was first marketed in 1976.

They evolved originally as a result of the search for a replacement for the silicate cements that had been used in dentistry for about one hundred years. It was also hoped that, following the development of the polycarboxylate cements, it would be possible to develop another, stronger material that would adhere long-term to dental structures. The silicates were useful because they released fluoride; but, because they were never really properly understood, they were badly abused by the profession, and never reached their full potential. It is essential now that the profession come to terms with this new family of materials and learn to understand and appreciate them, so that this time they can live up to expectations and be recognized as the only biologically active restorative material currently available.

The glass-ionomers are probably more accurately and scientifically known as glass–polyalkenoate cements. They are a true acid–base material, where the base is a fluoroaluminosilicate glass with a high fluoride content, and this interacts with a poly(alkenoic acid). The result is a cement consisting of glass particles surrounded and supported by a matrix arising from the dissolution of the surface of the glass particles in the acid. Following mixing of the two components, calcium polyacrylate chains form quite rapidly and develop the initial matrix that holds the particles together. Once calcium ions are involved, aluminium ions will begin to form aluminium polyacrylate chains, and, since these are less soluble and notably stronger, the final matrix formation takes place. At the same time some of the fluoride is released from the glass in the form of micro-droplets that lie free within the matrix, but play no part in its physical make-up. More fluoride is retained in the matrix, bonded to aluminium, and most of the subsequent fluoride release is the result of ion-exchange reactions. Thus the fluoride is able to leach out of the restoration as well as return into it with no modification at all to the physical properties of the set restoration. This means that a glass-ionomer, in any form, can be regarded as a fluoride reservoir. The fluoride is used initially as a flux in the manufacture of the glass, and it then becomes an essential part of the setting reaction. It represents approximately 20% of the final glass powder and, following mixing and setting, the fluoride becomes available from the matrix more readily than from the original glass particles.

Somewhere between 11% and 24% of the set cement is water, so that a glass-ionomer can be accurately described as a water-based material. The water content has been somewhat arbitrarily divided into 'loosely bound' water, which is easily removed by dehydration, and 'tightly bound' water, which cannot be removed, and remains an important part of the setting reaction as well as of the finished set cement. It is essential to be aware that, in the early stages following mixing,

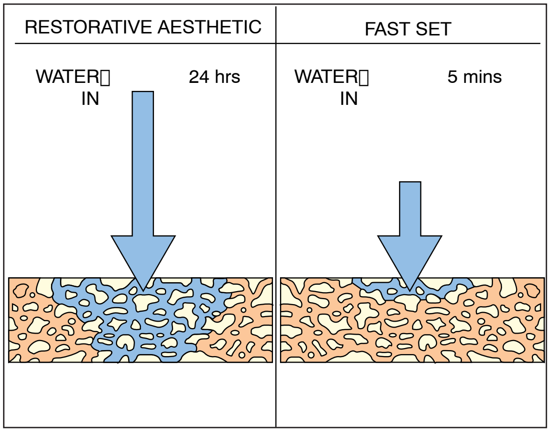


Figure 1.1

Diagrammatic representation of the water balance in the glass-ionomers. The Type II.1 restorative aesthetic materials remain susceptible to water uptake for at least 1 day after placement. All other Types are fast-setting glass-ionomers, and so are resistant to water uptake within 5 to 6 minutes of the beginning of mix.

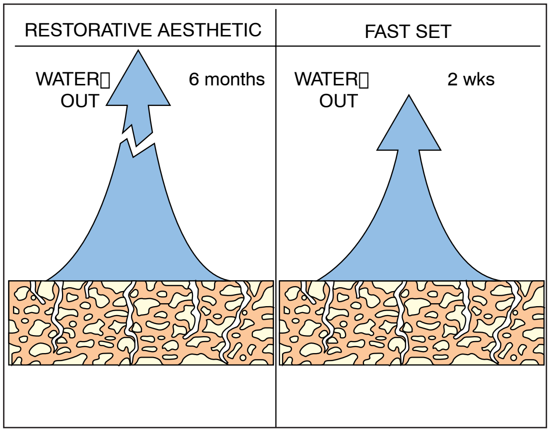


Figure 1.2

The problem of water loss continues for a longer period for both the fast- and the slow-set Types, and precautions must be taken to prevent dehydration.

and prior to the final set, the calcium polyacrylate chains remain highly soluble in water, and this means that further water can be taken up into the immature cement. Conversely, the loosely bound water can be lost by evaporation if the cement is exposed to air. This problem of water loss or water uptake, that is, the water balance, is probably the most important and least understood problem with this group of materials (Figures 1.1 and 1.2). However, achievement of rapid resistance to water uptake can be gained; but only with the sacrifice of some degree of translucency. A rapid-set material can be developed, during the manufacturing process, by stripping excess calcium ions from the surface of the glass particles in an acid bath. The aluminium ion exchange will then commence earlier in the process of setting, and rapid water uptake will be less of a problem. Ultimate physical properties will be enhanced, but translucency will be reduced or lost, and it will still be possible to lose water from dehydration if a restoration is left exposed for any length of time.

Recent modifications to the setting reaction, through the inclusion of a small quantity of resin, have led to the development of the resin-modified materials. It seems that the resin will provide some degree of protection for the setting reaction, in the short term immediately following light-activation, preventing further water uptake or water loss without any substantial modification to the acid–base setting reaction. There will be some modification, including a slowing down of the acid–base reaction, because of the cross-linking with the resins; but the clinical placement routines have been simplified and the physical

properties are, in fact, increased. In the longer term, of course, the resins themselves will take up water and lead to a degree of swelling in the ultimate restoration, with some loss of wear resistance. The terms 'auto cure' and 'dual cure' were arbitrarily introduced to differentiate between the two main setting reactions, without defining the actual chemistry that may be taking place in any one material. However, the term 'resin-modified' is now the preferred description for the latter group, because 'dual cure' is arguably a misnomer; and the term 'conventional' is now often applied to the original auto cure materials.

The original versions of the resin-modified materials were set initially via light-activation alone. Recently there have been a number of resin-modified materials released to the market in which the entire setting reaction is auto cure, thus requiring no light-activation at all. There have been additional setting mechanisms incorporated, such as a reduction/oxidation process designed to ensure the complete setting of any polymer chains that may have been excluded from the initial reaction. However, while resistance to water uptake will be rapid in all modern materials, complete maturity and resistance to water loss will still not be available for at least 2 weeks for any of them, and they can still dehydrate if left exposed within this period.

NOTE

It is important to be aware that the constituents of the various glass-ionomers on the market are not the same. There is, in fact, a considerable difference between the powders and liquids produced by various manufacturers; powders and liquids from different products must therefore never be interchanged. It should also be noted that, in some cases, materials marketed under different names are made by the same manufacturer.

Types of glass

Chemically the glasses used are very similar to those used in the old silicate cement formula. They are special aluminosilicate glasses, and until quite recently they were almost exclusively calcium aluminosilicate. However, there are advantages in the use of either strontium or lanthanum to replace some or all of the calcium, inasmuch as these elements introduce a degree of radiopacity. Provided the Al–Si ratio is high enough any of these glasses will be decomposed by acid and release cement-forming ions. They will all contain fluoride at some level, and this is there to lower the temperature of glass fusion, to improve the handling properties of the cement mix, to increase the strength and translucency of the set cement and to enhance the fluoride release.

There are a great number of glasses that could be used, and the formulae can be very complex. However, the two essential glass types that make a successful glass-ionomer are either SiO_2-Al_2O_3-CaO or SiO_2-Al_2O_3-CaF_2. Generally Na_3AlF_6 is added as a flux to lower the temperature of fusion.

Considerable research has been conducted into the actual constituents of the glass as well as the methods of manufacture, but there is still a need for further research in this area. The heat history of the melt is of significance, and the temperature at which the frit is quenched will have a bearing on the surface reactivity of the ultimate powder. At present there is some attention being paid to the powder particle size and particle size distribution. It has been shown that a reduction in particle size will enhance the reactivity of the glass powder and modify the setting reaction, and this can lead to an increase in the ultimate physical properties. In the early glass-ionomers the particle size ranged from 45 μ for restorative aesthetic cements down to 15 μ for a luting cement. Now the size has been reduced still further, in much the same way as has been done for the composite resins. The modern material will have a particle size range from 15 μ down to 1 μ. Further treatment may be employed to decrease the surface activity of the powder by annealing at 400–600°C and/or by washing in dilute acetic or hydrochloric acid.

Types of polyalkenoic acid

The big breakthrough in the advance from silicate cements came with the realization that some of the polyalkenoic acids would not only make a cement when mixed with glass but would also bring about an ion-exchange adhesion to tooth structure. The chosen acids at this point are generally homo-polymers of acrylic acid and its

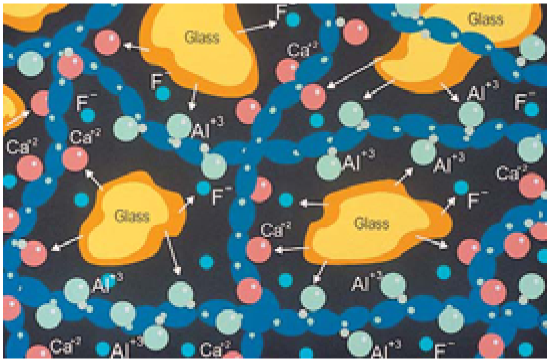


Figure 1.3

A theoretical diagram of the acid–base setting reaction between the glass powder and the poly(alkenoic acid). Note that only the surface of each particle is attacked by the acid, releasing Ca and Al ions as well as fluoride ions, which remain free and are not part of the matrix. The calcium polyacrylate chains form first, and then the aluminium polyacrylate chains follow immediately. See the next illustration for the final set material.

co-polymers with itaconic acid, maleic acid and other monomers. It must be noted that the liquid supplied by the manufacturers is not necessarily a polyacrylic acid, because this can be dehydrated and incorporated as a powder with the glass (Knibbs et al, 1986). Under these circumstances the liquid will be either water or an aqueous solution of tartaric acid. In its dehydrated form, polyalkenoic acids of higher molecular weight can be used, and physical properties will be higher. Under these circumstances the cement is somewhat easier to hand-mix on a slab, the viscosity of the mix is lowered, and the resulting mix flows more readily.

It was originally suggested that the maximum molecular weight that could be clinically useful was about 75 000 MW at a concentration of 45% by mass. It has subsequently been shown that with a higher MW the concentration must be reduced, but with a lower MW the concentration can be increased. Beyond these limitations there will be a sharp increase in viscosity, making it almost impossible to achieve a useful mix. However, as the molecular weight increases, the strength, fracture toughness and resistance to erosion will increase. On the other hand, setting time will be accelerated and working time lost, so there are restrictions placed on that avenue for improvement in the ultimate material.

Glass-ionomers were not clinically viable until Wilson and Crisp discovered the action of (+)-tartaric acid as a reaction-controlling additive. It is now regarded as an essential constituent, and appears in all formulations at a level of 5–10% of the liquid. It prolongs the working time by preventing the premature formation of calcium polyacrylate chains. It also sharpens the set and increases the hardening rate by enhancing the formation of the aluminium polyacrylate chains. In addition, it has a beneficial effect on the early strength.

Setting reaction of the auto cure cements

With the original conventional auto cure (chemically set) cements the acid–base reaction initiated by the application of poly(alkenoic acid) to the surface of the glass particles is, in fact, very prolonged (Figure 1.3) (Mount et al, 1982). There are four overlapping stages that can be identified but not clearly separated out.

1. Following mixing of the two constituents, the glass will be attacked by the polyalkenoic acid, so that the surface of the glass particles decomposes and releases metal ions, fluoride and silicic acid (which will later condense into a silica gel that will surround the glass particles).
2. As the pH of the aqueous phase rises the polyalkenoic acid will ionize and create an electrostatic field that will aid the migration of the liberated cations into the aqueous phase.
3. Polymer chains will then unwind as the negative charge increases, and the viscosity will increase. The concentration of cations will continue to increase, and they will condense

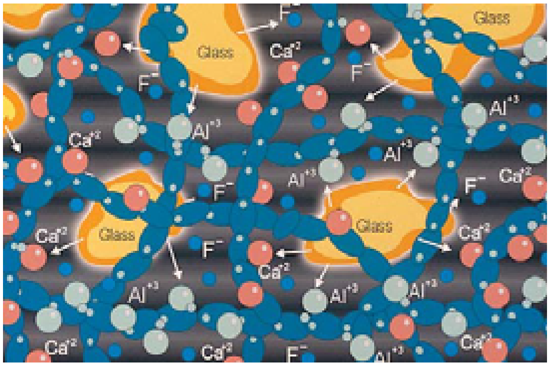


Figure 1.4

It will take some time for the glass-ionomer to set fully and mature. Note that at this time there is a degree of maturity, with more calcium and aluminium chains. There is also a halo of a siliceous hydrogel surrounding each of the glass particles, and it is thought that this will increase resistance to acid attack. It has been noted that these chains can break and re-form throughout the life of the restoration.

on to the polyacid chain. Desolvation will occur, and insoluble salts will precipitate, first as a sol and then later as a gel. This initial set will occur within 4 minutes with either a luting cement or a restorative material, so that it is then possible to remove the matrix and carry out trimming of the newly placed restoration, provided always that the water balance is carefully maintained.

4. Following gelation the cement will continue to harden and mature as cations are increasingly bound to the polyanion chains and hydration reactions continue. A siliceous hydrogel will then begin to form around the surface of the glass particles (Figure 1.4). However, complete maturity and stability of the water balance will not be available for at least 2 weeks for the fast-setting varieties and possibly 6 months for the slow-setting, conventional aesthetic cements.

It has been suggested by Cook (1982) that the transfer of both aluminium and calcium ions from the glass will continue for at least 5 weeks, during which time both strength and modulus will increase. In fact, the reaction probably never ceases, because it has been noted that the strength continues to rise for more than a year; and it has been postulated that there is always a continuing slow diffusion of cement-forming cations, especially aluminium, seeking anionic sites (Fricker et al, 1991).

The ultimate microstructure of the set cement is partially degraded glass particles embedded in a matrix of calcium and aluminium polyalkenoates and sheathed in a layer of siliceous gel, probably formed just outside the particle boundary. It is thought that the silica gel may account for the fact that the glass-ionomers are highly resistant to acid attack.

Water balance

As was noted above, these are recognized as water-based cements, because they contain water and they make water during the setting process. At the time of setting there will be a critical water balance in the material. Some of the water will be bound in and cannot be lost; but initially there is a reasonable quantity that is loosely bound, and it must be recognized that, in the short term, the loosely bound water will remain free to move out of the restoration. This fact appears to pose a challenge in the eyes of some operators; but all that is necessary is that the problem should be acknowledged and the rules regarding placement followed with care. Immediately after placement, cements remain subject to dehydration through the loss of unbound water if they are left exposed to air. On the other hand, in the early stages there can also be further water uptake through dissolution of the rather weak calcium polyacrylate chains, and this will degrade physical properties and reduce translucency. However, it is a simple matter to cover and seal the restoration immediately the cement is set, and the clinical techniques involved will be discussed in greater detail on page 20. Most of the modern auto cure glass-ionomers are fast-setting materials, which means that this latter problem has been

overcome, although it does mean that they lack top-class translucency.

The water balance is most significant for the Type II.1 restorative aesthetic materials (page 13), where it is important to achieve translucency in the restoration but acceleration of the setting procedure is not possible. The clinician must accept the resultant problems of maintaining a stable environment for the newly placed restoration and take care to seal it for at least the first hour and preferably for the first day (Causton 1982). Thereafter, water uptake is of less significance, although water loss will remain a problem. If a relatively immature restoration is to be exposed again to potential dehydration in the first 6 months after placement, it should be sealed with a waterproof coating to help maintain the water balance.

Considerable effort has been expended over recent years on overcoming these problems of water balance, and the resin-modified materials are a direct result of this. There are now also a number of auto cure materials that show high early stability, although they lack the ultimate translucency available with the slower-setting varieties. It has been suggested that the profession is intolerant of the time taken up by the setting reaction, and that faster-setting materials, particularly lining cements, are necessary. Certainly, conservation of time is important during clinical placement; but it is even more imperative that the inherent advantages of ion-exchange union to enamel and dentine, as well as that of the continuing remineralization potential, are not reduced or eliminated in the process.

Setting reaction of the resin-modified light-cured materials

The full chemistry of the resin-modified materials is not yet fully understood (Sidhu & Watson 1995). A number of manufacturers have independently developed resin-modified glass-ionomers based upon methacrylate-functionalized carboxylic acids that are designed to undergo two separate setting reactions, which will ultimately cross-link (Mitra 1994). One of the earliest patent applications was registered in 1989, and there have been a number of modifications since that time.

There appear to be several modifications of the basic principle available, depending on which resins are included and also the relative proportion of resin compared to glass-ionomer. The hybrid material will have two distinct mechanisms for polymerization: the original acid–base setting reaction of a glass-ionomer and also a vinyl polymerization of acrylate groups that can be activated through the presence of photoinitiators such as camphorquinone. It is apparent that hydroxyethyl methacrylate (HEMA) is the resin of choice, and therefore a necessary ingredient to provide the vinyl reaction. However, it is highly hydrophilic, and may lead to water uptake over time (Sidhu & Watson 1998). There is also a risk of phase separation in such a situation where there are two matrices co-existing. Each manufacturer then adds further components with the object of protecting the original acid–base reaction between the ionomer glass and the poly(alkenoic acid) without inhibiting it. Some manufacturers add an additional component in the form of a reduction/oxidation catalyst system such as micro-encapsulated potassium persulphate and ascorbic acid. This so-called 'redox' catalyst allows for continuing polymerization in the absence of light-activation, thus ensuring the activation of any remaining HEMA. On average there is less than 25% HEMA in the liquid portion of the materials, as dispensed, so that, following mixing at a ratio of 3:1 or greater, there will be in the vicinity of 5–7% of HEMA in the set cement.

It must be noted that there is a reduction of water in the system, because some of it has been replaced with HEMA, and a lack of water in the glass polyalkenoate system is known to slow down the ionomer acid–base reaction. The initial set, therefore, will come from the polymerization reaction of the HEMA, and the subsequent acid–base reaction will then serve to harden and strengthen the already formed matrix. Of course, if there is dominance of resin and a serious insufficiency of water there will be no acid–base reaction at all, and the material will no longer be a glass-ionomer.

There is an assumption that, because of the continuing presence of the acid–base setting reaction, there is no concern with the depth of cure from the activator light, since any cement that is not light-activated will polymerize anyway. This is not entirely true, because, as was indicated

above, there is a certain lack of water and a change in polarity of the solvent, and therefore an inhibition of the acid–base reaction. This means that the glass-ionomer itself may not set as well as expected, and there may well be residual HEMA remaining, unreacted, in the lower levels of the restoration closest to the pulp. It has also been shown that there is a significant difference in the physical properties of the two phases, and that part of the restoration that has been fully light-activated is notably superior. Therefore, clearly, depth of cure is important, and incremental build-up is recommended if there is a limited mechanism incorporated for chemical curing of the methacrylate groups.

From the clinical point of view, the interaction between tooth structure and the glass-ionomer, which produces adhesion through the ion-exchange layer, is of paramount importance. Also the long-term fluoride release and ion exchange should not be interfered with. However, if the addition of further resins will protect these factors and allow the glass-ionomer acid–base reaction to continue, while at the same time enhancing the physical properties, then clinical placement will be simplified and the restoration may be more reliable. A simplified diagrammatic representation of the setting reaction is shown in Figures 1.5 and 1.6. The original acid–base reaction demonstrated in Figure 1.3 appears to continue without interruption, and the resin component, following light-activation, seems to provide an umbrella effect. The newly set cement will be protected from early loss of loosely bound water as well as further uptake of water through the dissolution of the calcium polyacrylate chains. There appears to be some degree of cross-linking between the two matrices, but both reactions seem to proceed without interference. Over time, any remaining resin not affected by light-activation appears to undergo a further chemical setting reaction (a 'dark cure reaction') similar to that which occurred with the original chemically cured composite resins. This has led to the use of the term 'tri-cure' or 'triple cure' by some manufacturers to describe the setting reaction of their material.

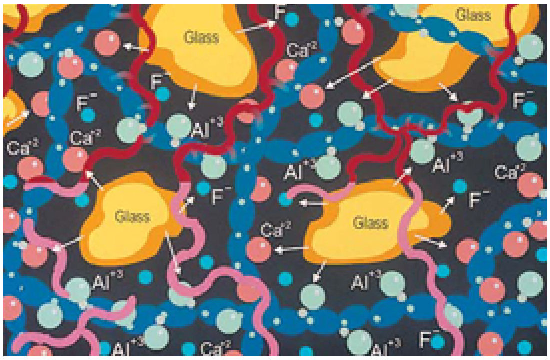


Figure 1.5

A theoretical diagram showing the influence of the resins incorporated into the glass-ionomer to convert it to a resin-modified material. The resins alone are light-activated to whatever depth is allowed by the penetration of the activator light. This appears to be sufficient to protect the acid–base reaction of the glass-ionomer from immediate water uptake and water loss. The red chains represent fully activated resins to the depth of penetration of the activator light. Note that there is already a degree of cross-linking between the polyalkenoic acid chains and the polymer chains.

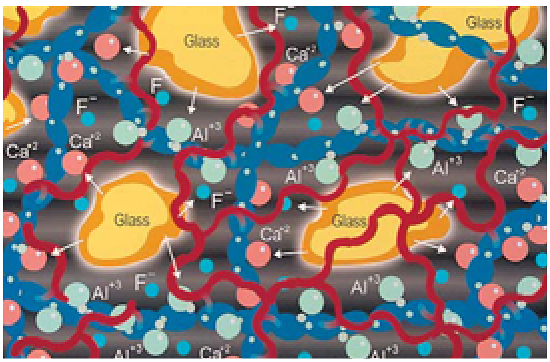


Figure 1.6

A theoretical diagram showing the progress of the chemical setting reaction of the resin component of the resin-modified glass-ionomer. Light-activation will be limited to the light penetration, but an auto cure (redox) reaction will continue until the entire cement/resin mass is set. The red chains now represent the completion of the auto cure setting of the resins. Note that the auto cure component of the cement is matured to the same degree as the auto cure materials (Figure 1.4), and now there is a complete cross-linking between the polyalkenoic acid chains and the polymer chains.

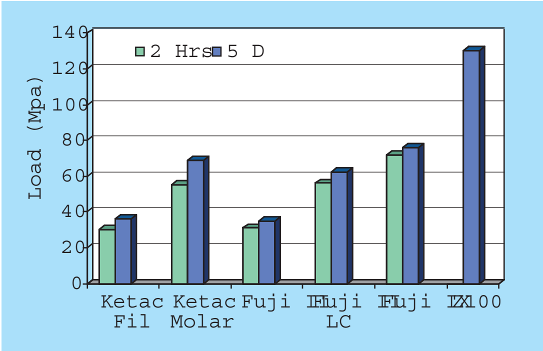


Figure 1.7

A bar chart showing the relative strengths of some auto cure materials as measured by a shear/punch test compared with the composite resin Z100. Note that each of the glass-ionomers is stronger at 5 days than at 2 hours – evidence of the continuing setting chemistry.

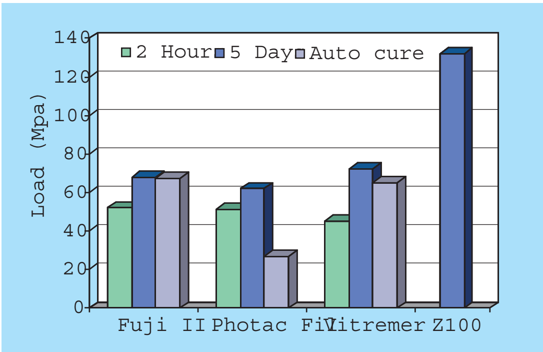


Figure 1.8

A bar chart showing the relative strengths of some resin-modified glass-ionomers as measured by a shear/punch test compared with the composite resin Z100. Note that each material is stronger at 5 days than at 2 hours – evidence of the continuing setting chemistry. Note also the strength of the specimens that were allowed to auto cure only for 5 days – evidence that the acid–base reaction can be altered in some materials by the presence of the resins.

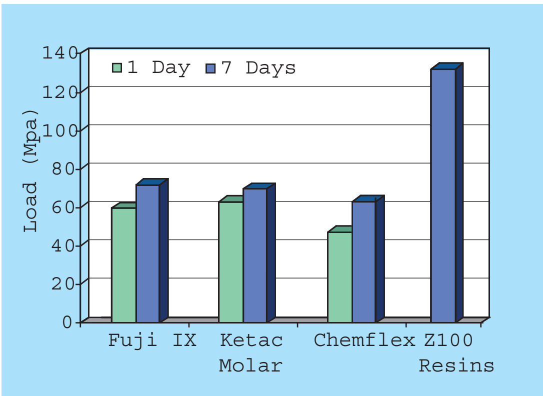


Figure 1.9

A bar chart showing the relative strength of the recent high-strength auto cure materials as measured by a shear/punch test and compared to the composite resin Z100. Note that even at one day the strength is acceptable, but that at seven days they are the strongest materials currently available. They are beginning to compare quite favourably with the micro-fil composite resins.

Recent laboratory investigations suggest that the above description is a reasonable hypothesis. Tests show a continuing improvement in the physical properties over the first 7 days for conventional auto cure glass-ionomers as well as resin-modified materials (Figures 1.7, 1.8 and 1.9), suggesting that the chemical setting reaction has not been inhibited. Specimens of the latter, maintained in the dark, free of any light-activation, will begin to set chemically within 5–7 minutes, and, in some materials, will achieve physical properties only a little lower than those achieved by light-activation. Translucency testing shows that the resin-modified materials react in a similar fashion to the auto cure glass-ionomers. Following light-activation, translucency declines marginally over the next 24 hours; but within a week the cement is more translucent than originally. Furthermore, placement of the specimens in water immediately after light-activation will not

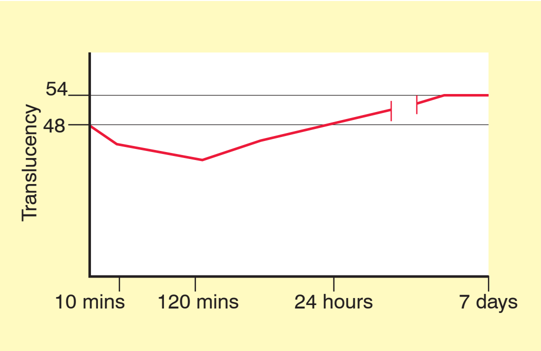


Figure 1.10

A chart showing the initial decline in translucency of a resin-modified material over the first 24 hours after mixing, followed by an increase over the following 7 days to a point where the cement is more translucent than it was initially.

modify this effect (Figure 1.10). The depth of cure of the cement as the result of light-activation is consistently 3–4 mm, but, owing to the ongoing acid–base setting reaction, this is not highly significant. With some materials, any resin not cured by light will continue to set because of the redox reaction provided, so that the restoration will achieve physical properties that will be relatively uniform throughout. This appears to provide a safety margin in the average restoration, inasmuch as unreacted cement below 4 mm will set and achieve physical properties which, although lower than normal, may be acceptable. However, it is suggested that the ion exchange between tooth structure and the auto cure component in some of the resin-modified materials may not be fully effective, so that incremental build-up is always recommended to ensure maximum properties (Burrow & Tyas 1998, 1999).

Incremental build-up is probably the safest way of placing any light-activated restorative material, because there is inevitably some degree of shrinkage due to the immediate setting reaction in the direction of the light. This may be controlled to a certain extent by careful placement of the light, but some degree of stress on the newly forming ionic bonding is almost unavoidable. The shrinkage in the resin modified glass-ionomers seems to be minimal, but it does exist and therefore caution is required.

There are a number of fundamental criticisms that can be directed towards the resin-modified glass-ionomers. To some extent they go against the philosophy of the glass-ionomers inasmuch as they contain a monomer. Monomers are toxic, and HEMA is no exception. This means that there may well be a degree of risk in their use for some patients, as well as for operators and their staff, through a relative lack of biocompatibility and the potential for an allergic response. HEMA is strongly hydrophilic, and the set material will take up water, leading to both expansion and a lowered resistance to wear and erosion. The resin-modified materials have also shown a potential for colour change over time, particularly in a mouth that is not well maintained (Doray 1994). Finally, the addition of a low-molecular-weight monomer, such as HEMA, to a glass-ionomer will lead to an increase in polymerization shrinkage as well as a substantial exotherm that can last for some time. While initially they are stronger than the original conventional glass-ionomers, there are now a number of conventional materials with superior properties. The clinical significance of these differences is not great; but they mean that the resin-modified materials should not be regarded as necessarily an improvement upon the auto cure system (Figures 1.8 and 1.9).

Setting reaction of the resin-modified auto cure material

Variations on the resin-modified materials include ones that are either fully auto cure or else subject to a combination of light/heat plus auto cure. For these materials the powder component will generally be very finely ground, although the fineness will vary according to its proposed function. There will also be a small quantity of a catalyst incorporated, which is designed to stimulate the auto cure reaction of the resin component. The liquid will contain the usual polycarboxylic acid,

tartaric acid, water and HEMA, as well as a small amount of a cross-linkable monomer. Some products also claim to contain a polycarboxylic acid modified with pendant methacrylate groups.

Following mixing of the powder and the liquid the usual acid–base setting reaction will be initiated. At the same time the catalyst in the powder will initiate polymerization of the HEMA and the cross-linkable monomers. Ultimately, there will be cross-linking between the two systems and the entire mass will set hard, with uniform physical properties, in spite of the fact that there has been no light-activation at all.

Most of these are luting or lining materials, and are of value where it is not possible reliably to light-initiate the setting reaction. They have a higher flexural and bonding strength, and may be particularly useful for orthodontic bracket and band cementation. At present the materials already on the market have relatively low physical properties, commensurate with the tasks designated to be performed; but there is a probability that the same principle will be applied with stronger materials such as dental restoratives in the future.

Setting reaction of the light-initiated auto cure material

Another variation incorporates a method for speeding up the setting reaction of the auto cure materials. This involves enhancing the speed of the acid–base setting reaction by utilizing a simple physical principle. If a dye is incorporated in a glass-ionomer and the colour is specified, such that the L* value, when expressed by an L*a*b* colorimetric system in a standard light D_{65}, is 60 or less, the curing reaction will be further promoted and the setting reaction will be speeded up. Thus if a glass-ionomer is coloured red, and then mixed, placed and irradiated by the standard blue dental halogen activator light, the acid–base setting reaction, which is already under way, will take place more rapidly. The material can now be regarded as light-initiated; but there is a complete absence of any added resin. Setting time will be dramatically reduced; but there will be no significant generation of heat, and the physical properties of the set material will not be downgraded in any way.

This factor has recently been incorporated into a low powder:liquid ratio glass-ionomer to which has been added a small quantity of a red pigment. As an additional benefit it appears to be highly bactericidal, so that because of its rapid command set, it can be recommended for a number of applications:

- as a fissure protection material in situations where aesthetics is of no concern or possibly for an uncooperative patient where speed is desirable (Figure 7.18).
- as a root-surface protection material it may be useful in the early stages of root-surface caries. It will flow well, the colour will be in keeping with gingival tissue, and its antibacterial properties may be useful.
- it can be used as a lining or base in a very deep cavity that will need to be explored again. It will then be identifiable during removal of any material that has been placed above it, and the operator will become aware of approaching the floor of the cavity (see Figure 2.15).
- as a transitional restoration during a stabilization phase in a caries-active patient.
- as a temporary seal for endodontics.

Other tooth-coloured materials – e.g. compomers and composites

There is some confusion in the market, because the term ‘glass-ionomer’ is being used rather loosely by some manufacturers, and comparisons are being drawn with materials that cannot be classified as glass-ionomers. As was suggested earlier, it is entirely possible to include a polymer in a glass-ionomer. Similarly it is possible to include some of the constituents of a glass-ionomer in a composite resin (a polymer). The essential elements of a true glass-ionomer are:

- acid–base setting reaction;
- ion-exchange adhesion with the underlying tooth structure; and
- continuing ion activity, with mobility of fluoride, calcium and phosphate ions.

For these to be available it is necessary to have both water and a poly(alkenoic acid) present in the formula in an ionizable form. As the balance

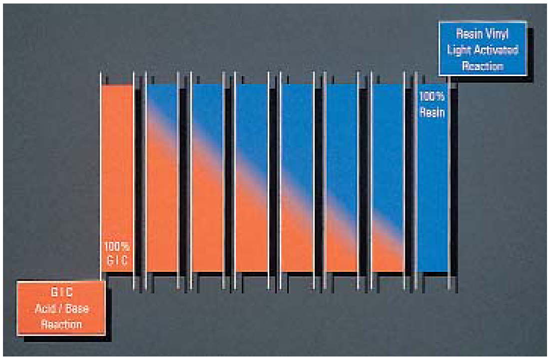


Figure 1.11

A diagram showing the theoretical composition of various resin-modified materials and the potential effect of modifying the relative percentage of the contents. As the resin component increases, the acid–base reaction reduces, until the benefits of the glass-ionomer are lost and the material becomes a light-activated material only. The compomers would belong in one of the middle two bars, so the acid–base component is negated, and they therefore belong to the composite resin end of the table.

in the formula moves further to the right (Figure 1.11), away from the acid–base reaction, and the resin component (polymer) becomes predominant, the material is no longer a glass-ionomer, and should not be placed in that category.

When the compomers were first marketed it was claimed that they had all the advantages of both glass-ionomer and composite resin in the one material (Meyer et al, 1998). However, according to the above description this is not possible, because a compomer is predominantly an anhydrous resin-based material. This means it is not possible to have ion transport within it. Any fluoride release will therefore be minimal and transitory, and adhesion to tooth structure can only be developed via a resin-bonding agent.

McLean et al. (1994) defined the categories to elucidate the situation and try to eliminate any confusion. They set out the classification of the tooth-coloured restorative materials in the following series, and this can be identified through Figure 1.11.

1. Glass-ionomer – auto cure, water-based
2. Resin-modified glass-ionomer – light-initiated and auto cure, water-based
3. Poly-acid modified composite resin – light-activated, anhydrous, possibly with an ionomer glass as a filler
4. Composite resin – light-activated, anhydrous with other types of filler

The poly-acid modified composite resins will generally contain an ionomer glass as the filler (or part of the filler), and some of them will also contain some form of dehydrated polyalkenoic acid. It is suggested that the polyalkenoic acid will eventually become hydrated following water uptake (from the saliva) into the restoration, and this may then lead to an acid–base reaction. However, it will not be possible at that point to develop an ion-exchange adhesion to underlying tooth structure, because there will already be a resin bonding agent separating the restoration from the tooth. It is also unlikely that prolonged fluoride release will become available, because of the anhydrous nature of the resin matrix. This suggests that surface fluoride will only be released over a limited period of time, and the reservoir effect will be limited. All of this means that most of the normal glass-ionomer benefits have been negated, and the compomers are simply another form of a hydrophilic composite resin.

There are now several materials in this category available to the profession, and some of them are marketed in such a manner as to be confusing. They can be quite useful materials when used as indicated by the manufacturers, but it should not be expected that they will provide the properties normally identified with the glass-ionomers. The most obvious difference between the two types of material is that the proper resin-modified glass-ionomer is a true dual cure (or a tri-cure) inasmuch as it will undergo a chemical cure in the absence of light-activation. This means that the simplest method available to the clinician to differentiate between the two is to make a trial mix and retain it under a light-proof cover for 7–10 minutes. At this point the cement should be showing clear signs of a chemical set; and over the next 15–20 minutes, still protected from light, it should become quite hard. A non-glass-ionomer will stay very soft and rubbery, or else not set at all (Figures 1.12–1.15).

Figure 1.12

This is the simplest method for the operator to test whether a material is a compomer or a genuine glass-ionomer. Make a trial mix of the material and place it under a light-proof cover. Set the timing clock and check for degree of set at 5 minutes and each 5 minutes thereafter.

Figure 1.13

At 20 minutes the mix shown above is tested again for degree of set and it is apparent that this particular material shows no sign of setting at this point. It is therefore a compomer.

Figure 1.14

A similar trial mix of a resin-modified glass-ionomer is set against the timing clock.

Figure 1.15

At 7 minutes the material is well on the way to being set and, obviously, the acid–base reaction is taking place.

It is therefore suggested that the compomers be used carefully, with an understanding of their limitations, inasmuch as they show all the inherent problems associated with composite resins. Biologically they appear to be quite bland, and they show a steady decline in strength over time as plasticization occurs. There is sufficient water sorption and solubility to lead to considerable expansion, as well as to loss of unconverted monomeric material. In fact, there have been reports of fracture due to water uptake of ceramic crowns that have been luted with these cements. They can be used in restorative situations where they are not subject to undue occlusal load and without the expectations for longevity and caries-resistance associated with the true glass-ionomers.

Classification

The following classification for glass-ionomers is adapted from Wilson and McLean (1988). It is generally accepted, and will be used throughout this book.

Type I: Luting and bonding materials

- For cementation of crowns, bridges, inlays and orthodontic appliances as well as bonding of composite resins and amalgam.
- Powder–liquid ratio approximately 1.5:1 or up to 3.8:1 if the polyacid is dehydrated and incorporated in the powder.
- Fast set, with early resistance to water uptake or light-activated.
- Ultimate film thickness 20 μm or less.
- Radiopaque.

Type II: Restorative

II.1: Restorative (aesthetic) auto cure and resin-modified
- For any application requiring an aesthetic restoration with minimal occlusal load.
- Powder–liquid ratio 3:1 but up to 6.8:1 if the polyacid is dehydrated and incorporated in the powder.
- Excellent shade range and translucency.
- Auto cure cements have a prolonged setting reaction and remain subject to water loss and water uptake for at least 24 hours after placement; they require immediate protection from the oral environment.
- Resin-modified materials are immediately resistant to water uptake or water loss; they do not require sealing.
- Most materials are radiopaque.

II.2: Restorative materials
- For use where aesthetic considerations are not important, but a rapid set and high physical properties are required.
- Powder–liquid ratio 3:1 to 4:1.
- Fast set with early resistance to water uptake; can be trimmed and polished immediately after initial set; remain susceptible to dehydration for 2 weeks after placement.
- Radiopaque.

Type: III Lining or base cements

- Can be auto cure or resin-modified.
- Can be used as either a lining or a base, depending on the powder–liquid ratio used.
- Powder–liquid ratio about 1.5:1 for use as a lining material under other restorative materials.
- Powder–liquid ratio 3:1 or up to 6.8:1 for use as a base or dentine substitute in lamination technique with another restorative material.
- Physical properties improve as the powder content increases.
- Radiopaque.

There are a number of variations of the above categories developed for specific applications. A luting cement for orthodontic appliances, bands and brackets is similar to the standard luting cements, but the setting time has been extended to allow a generous working time. A further variation to this is a resin-modified material that enjoys some of the advantages of command set. There is still an acid–base setting reaction occurring, so that the command set is not as broad as it is with a composite resin. One of the major advantages of using a glass-ionomer in orthodontics is that it is relatively easy to use and to remove. Whereas a resin cement will penetrate deeply into enamel, and possibly take a piece with it on removal, a glass-ionomer will fail cohesively when removed, and the remainder can be simply polished off.

A further variation is designed as an endodontic cement, also with a rather prolonged working and setting time and an increase in radiopacity. This belongs in the Type I category because of the powder–liquid ratio, but is not meant to

achieve high ultimate physical properties because it may have to be removed at a later date if the root-canal therapy fails. However, it has the advantage of high tissue tolerance and a possible antibacterial effect.

Significant factors

Powder–liquid ratio

As with all dental restorative materials, the powder–liquid ratio has a significant bearing on ultimate physical properties. To a certain extent, the greater the amount of powder incorporated into the liquid the higher the ultimate physical properties. However, where there is insufficient liquid to wet the powder particles, a point will be reached where translucency will decline and physical properties will be reduced because of inherent faults and voids. It must also be noted that the recommended ratio will be dependent upon the type of liquid supplied by the manufacturers – hydrated or dehydrated polyacrylic acid. If a dehydrated polyacrylic acid is used then the powder component will be necessarily greater.

Low powder ratios are required with the luting cements so that optimum film thickness can be achieved. Also, when using the cement in small quantities as a lining under other restorative materials, such as amalgam or gold, it is more readily handled with a lower powder content. Under these circumstances physical properties will not be of great significance. Physical properties will be reduced and solubility will be increased, and therefore these linings must not be exposed directly to the oral environment.

On the other hand, if the glass-ionomer is to be used as a base under composite resin then optimum physical properties will be essential and a high powder–liquid ratio is indicated. The resultant material can then be exposed to the oral environment, because it will have all the properties of a complete restoration and the aesthetic component may not be quite so significant (Kirby & Knobloch 1992).

Dispensing

The use of capsulated materials is strongly recommended. At this time most of the reputable manufacturers use one of the reliable capsule systems; and, even though this increases the cost marginally, the reliability of the end-result fully justifies the expense. The only caution is to ensure that the capsule is fully activated before placing it in the mixing machine, so that all the liquid will be dispensed, without leaving any behind in the reservoir. Follow the manufacturer's instructions with care. The powder–liquid ratio will now be standardized, as well as the mixing and setting times. Achievement of ultimate physical properties will not be in doubt.

Hand-mixing of all glass-ionomers is possible, but considerable variation in the proportions will result unless extreme care is taken in measuring out when dispensing. When it is recommended by the manufacturer, shake the bottle of powder to fluff it up, and then use the spoon supplied for that particular material. Level off the powder in the spoon on the lip of the bottle and make sure there is no excess on the outside of the spoon before emptying it completely on to the slab or pad (Figure 1.16).

The liquid droppers from most manufacturers are reasonably accurate, but the spout must be kept clean of dried accumulations by periodically wiping it with a damp cloth. If the liquid is polyacrylic acid it will be rather viscous. To dispense accurately turn the bottle horizontal first and allow the liquid to flow into the spout. Then turn vertically and dispense a drop that is free of air bubbles (Figures 1.17, 1.18).

The only truly accurate method of dispensing by hand is to use a balance that will record to 2 decimal points; but that is impractical in the clinic. However, it must be noted that a 10% variation – plus or minus – is easily achieved with either powder or liquid, and this means there is a potential for an accumulated error of up to 20%. This is sufficient to modify the physical properties to at least the same extent.

There is a further variation in dispensing recently available, using a two-paste system packaged in a twin-syringe apparatus. At the moment this presentation is available as a resin modified luting cement only, and the main attraction lies in the ability to dispense variable quantities with the correct ratio at all times. It utilizes a fine powder particle size, leading to an ultimate

Figure 1.16

Dispense the powder with care, because it is difficult to standardize the amount in the spoon. Shake the bottle (if instructed by the manufacturer) and then tap it once only on the bench top to settle the powder away from the lid. Lift out a spoonful and level it off using the lip on the bottle. See that there are no hollows in the surface nor excess powder on the bottom of the spoon. Dispense it on to the slab or pad.

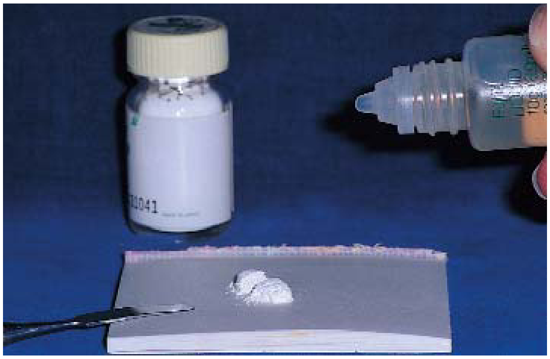


Figure 1.17

If the liquid is polyacrylic acid it is easy to include an air bubble in with the drop of liquid. Tilt the bottle horizontal first, and pause a moment to allow the rather viscous liquid to flow into the spout.

Figure 1.18

Now completely invert the bottle and squeeze gently. Hold the bottle about 1 cm off the pad, and a clean drop of liquid, free of an air bubble, will be dispensed.

film thickness of well under 5 μ, and the setting time is around three minutes. There has been an increase in the resin content as well as the inclusion of traces of a catalyst to bring the auto cure reaction of both the glass-ionomer and the resin component to completion. No doubt work will continue to make this type of presentation available as a restorative material.

Mixing

When mixing capsulated materials mechanically, care must be taken to see that the correct time is used according to the machine available. Manufacturers generally suggest 10 to 15 seconds (varies with the material) with a machine capable of 4000 cycles/min. These are

generally known as 'ultra-high-speed' mixers, but some machines will produce up to nearly 5000 cycles/min, and older-style machines can be reduced to 3000 cycles/min, just through age. This may therefore, inadvertently, lead to either over- or under-mixing, resulting in loss of homogeneity, alterations in working time and, more importantly, to adhesive potential. An estimation of the effective working time for each machine can be made by determining the 'loss of gloss' of the newly mixed material (see Box A, page 18). Careful observation of a sample mix will show when the gloss disappears, and subsequent placement of the cement will risk modification to adhesion because of a lack of free polyacrylic acid. Working time should be

Figure 1.19

Divide the powder into two equal parts. Set the timing clock and take the first half of the powder into the liquid. Roll the powder into the liquid to wet the surface of each particle and produce a thin wet mix.

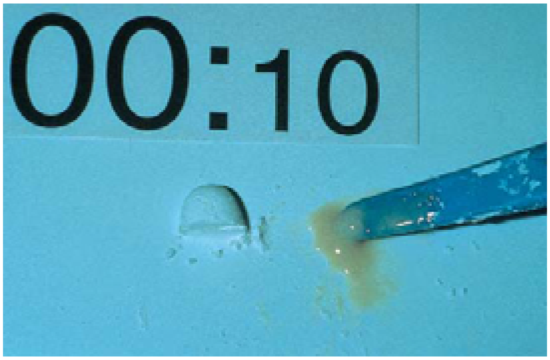


Figure 1.20

After 10 seconds incorporate the second half of the powder and continue spatulating, gently and thoroughly, to wet all the powder. Keep the mass together and do not spread it too far on the pad. Try to avoid breaking up the powder particles – just wet the surface and that is all.

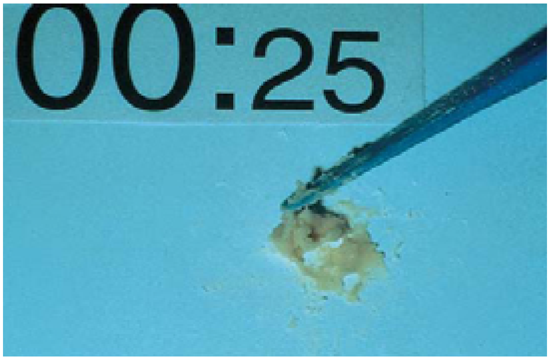


Figure 1.21

By 25 seconds – 30 seconds at the maximum – the mixing should be complete. Do not play with the mix to judge its consistency, because this will only continue the mixing process and dissolve more powder.

Figure 1.22

Promptly collect the newly mixed material into a disposable syringe and prepare to place it into the cavity. The acid–base setting reaction is already under way.

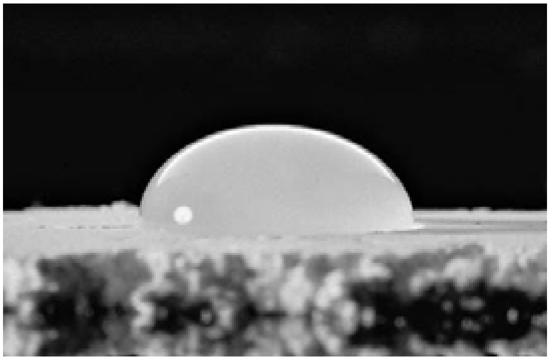


Figure 1.23

A drop of polyalkenoic acid has been placed on top of a pile of standard glass-ionomer. Note the apparent reluctance of the liquid to be absorbed into the powder. (Illustration courtesy ESPE GmbH.)

at least 2 minutes from the completion of mix, and this will normally be achieved with a mixing time of 7–10 seconds. A shorter mixing time may leave unreacted liquid visible in the cement, while a longer period may result in increased viscosity and an unacceptably short working time.

There is an art in correct hand-mixing, because of the potential for variation in proportions and the limited time available before the setting reaction begins, following which further mixing is contraindicated (Figures 1.19–1.22). Dispense the liquid immediately before mixing – do not leave it to lie on the pad or slab, because it may take up water. Begin by spreading the liquid out on the pad or slab and then immediately incorporate one half of the powder with the spatula. Mix this in as rapidly as possible by rolling the powder into the liquid without spreading the mix too far around the pad. At 10 seconds add the remaining powder and continue mixing with a rolling motion. Keep the cement mass together and simply wet the surface of the powder particles, trying not to dissolve them entirely. By 30 seconds the mix must be complete. Cease mixing immediately, and transfer the material to a disposable syringe. Any continuation of handling will begin to break up the newly forming polyacrylate chains and weaken the ultimate material.

One of the original problems with hand-mixing was the relative reluctance of the liquid actually to wet the powder particles. For example, if a drop of liquid is placed on the top of a pile of powder (Figure 1.23) it will show no sign of absorption, so some degree of persuasion is required, and mixing by hand becomes tedious. It has now been shown that agglomeration of the particles and elimination of the dust from the powder will improve the wetability of the powder and reduce this problem considerably

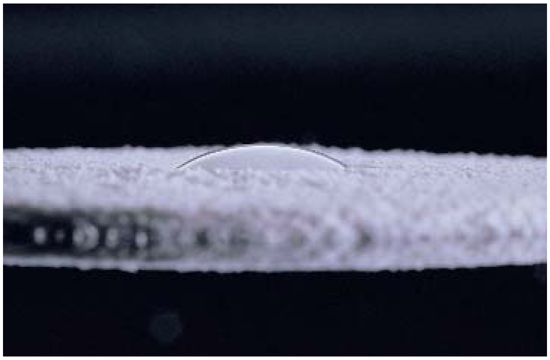


Figure 1.24

A drop of liquid has been placed on top of a pile of the new agglomerated powder. Note that the liquid has been immediately absorbed entirely into the powder showing the extent to which the powder is wettable. (Illustration courtesy ESPE GmbH.)

(Figure 1.24). As a result of capillary forces the liquid is absorbed into the granulated particles and, while the granulate is strong enough for transport, it will break down rapidly with mixing. There appears to be little or no change in the physical properties; but it is possible to achieve a suitable mix in less than half the time.

BOX A MIXING OF CAPSULES

Trituration of capsulated glass-ionomer is not necessarily a straightforward procedure. Manufacturers give a recommended time for capsules in a so-called high-energy capsule mixer, but it must be realized that not all mixers are the same and, probably more important still, all mixers can vary in the amount of energy dispensed on any given day.

- A high-speed mixer works at approximately 3000 cycles/min.
- Ultra-high-speed mixers work at approximately 4500 cycles/min.

However, the number of cycles may vary by as much as 10% on either side of this figure under normal circumstances, and factors such as ambient temperature, power surges, manufacturer variation, and age of the machine can produce much greater differences. The operator should therefore be prepared to check the state of the mix periodically to ensure a predictable and standard result. Check the efficiency of your machine by assessing the ‘loss of gloss’ of a freshly mixed capsule.

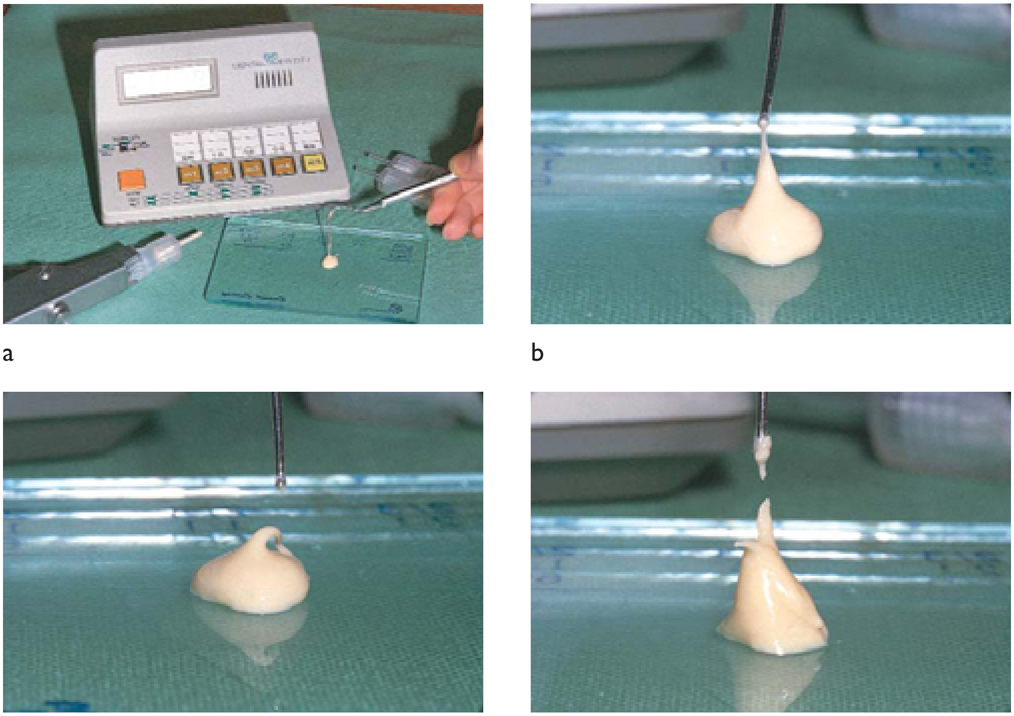
Determining the ‘loss of gloss’

- Mix a capsule for 10 seconds and express the contents on to a glass slab in a single pile. Start the timer (a).
- The material will have a wet glossy surface and will slump down on the slab without spreading out.
- Using a dental probe or a small ball-ended instrument, touch the top of the pile and lift the cement up. It should string up 2.0 cm or so from the top, then break away and slump back to its original shape (b,c).
- At some point, the glossy surface will begin to dull. The material will no longer string out as far as before, nor will it slump to its original form (d).

continued on the next page

- Note the time. Subtract 15 seconds from the total time, and the remainder is the effective working time available following mixing with that machine.
- Vary the mixing time as required to set the correct working time for your individual situation.
- Extending the mixing time may produce a mix that will flow better, but the rise in temperature produced by the increase in energy expended may reduce the working time quite dramatically.
- Reducing the mixing time may produce a mix that will flow more readily because not all the liquid has been incorporated. Working and setting time will then be considerably extended, but physical properties will be downgraded.

Bass EV, Wing G, The mixing of encapsulated glass-ionomer cement restorative materials, *Aust Dent J* (1988) **33**:243.



a b

c d

Porosity

There is a degree of porosity incorporated in all these materials, which is unavoidable because they are two-part materials that require mixing. There appears to be a greater variation in the size of porosities when the cement is hand-mixed, while machine-mixed capsulated materials show a similar quantity, but with smaller voids. The main hazard with porosity in these materials is a loss of compressive and tensile strength, because the voids may promote crack propagation.

Recent investigations have shown that it is possible to reduce the sum total of porosity by mixing at lowered atmospheric pressure, and this can lead to an average increase in strength of about 38% (Ngo et al, 1997a). However, elimination of all porosity is not possible and, in fact, would probably be undesirable, because it would reduce the plasticity of the mix and make it hard to place into a small cavity. So far the problems of developing a machine capable of mixing capsules at reduced atmospheric pressure have not been solved; but there is a machine available that employs a brief period of centrifuging the capsule immediately after mixing. This has shown an improvement in reduction of porosities as well as enhanced physical properties.

Time to mature – sealing a restoration

The setting reaction of the glass-ionomers can be described as an ionic cross-linking between polyacid chains, leading to a rigidly bound polyacid–salt matrix. The initial cross-linking involves the more readily available calcium ions, producing an early set to allow removal of the matrix. However, these divalent linkages are not stable and are readily soluble in water. The setting reaction continues within the hard cement mass, with further cross-linking by the less soluble trivalent aluminium ions. This second phase produces an increase in physical properties, along with a reduction in solubility, resulting in a hard, stable, brittle material with a highly linked polyacid–salt matrix. It is possible to increase the speed of this reaction by producing a dramatic reduction in the time taken for the development of the calcium polyacrylate chains and therefore an early resistance to water uptake and lowered early solubility. This can be achieved at the manufacturing stage by the removal of excess calcium ions from the surface of the glass particles, and this is the technique generally utilized for the new fast-setting materials. These materials require protection from dehydration only, and will be resistant to water uptake as soon as they are set hard.

This means that the conventional Type II.1 restorative aesthetic glass-ionomer is the only one for which it is imperative to provide early protection against water loss or water uptake. The maintenance of water balance for at least 24 hours is strongly recommended for this particular group, because it allows optimum development of aesthetics (Figures 1.26 and 1.27). Manufacturers provide a varnish to seal the newly placed restoration from the oral environment, but this has proved to be less than ideal. The varnish contains an evaporative vehicle, and this means that porosities are likely to develop through the varnish as the vehicle evaporates (Figure 1.28). If the varnish is carefully applied and the vehicle is evaporated by blowing it dry, followed by a second coat also blown dry, a reasonable result can be achieved.

The most efficient seal can be obtained by using one of the single-component, very-low-viscosity, light-activated, unfilled bonding resins, which are part of the composite resin system (Figures 1.25, 1.29–1.33) (Earl et al, 1985, 1989). Some manufacturers provide these with the kit. It has been shown that low viscosity permits better adaptation of the resin to the cement surface, and

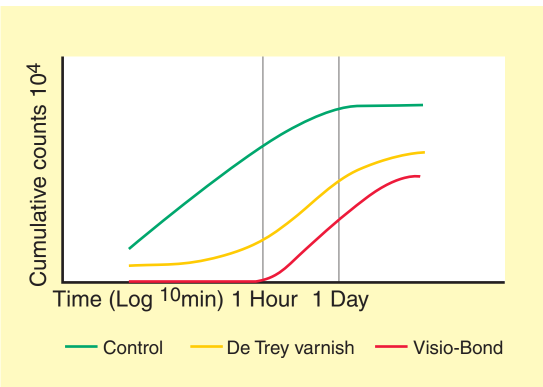


Figure 1.25

Relative efficiency of proprietary varnishes and of a single-component, low-viscosity, light-activated bonding resin as sealants in maintaining water balance within the cement. The table shows the amount of water passing through the sealants over time. The resin bond shows no water transport in the first hour and very little within the first 24 hours. This leads to better physical properties and greater translucency.

Control

Proprietary varnish

Low-viscosity, light-cured resin bonding agent

Figure 1.26

Cervical glass-ionomer restorations were placed in the upper-right canine and both bicuspids, 5 years ago. They were sealed immediately with a very-low-viscosity, light-activated bonding resin, and display excellent colour and translucency.

Figure 1.27

The same restorations as shown in Figure 1.26 photographed 12 years later. Note that there has been no obvious wear, and the colour match has changed only because the patient's teeth have matured. The first bicuspid recently lost the buccal cusp and has been crowned.

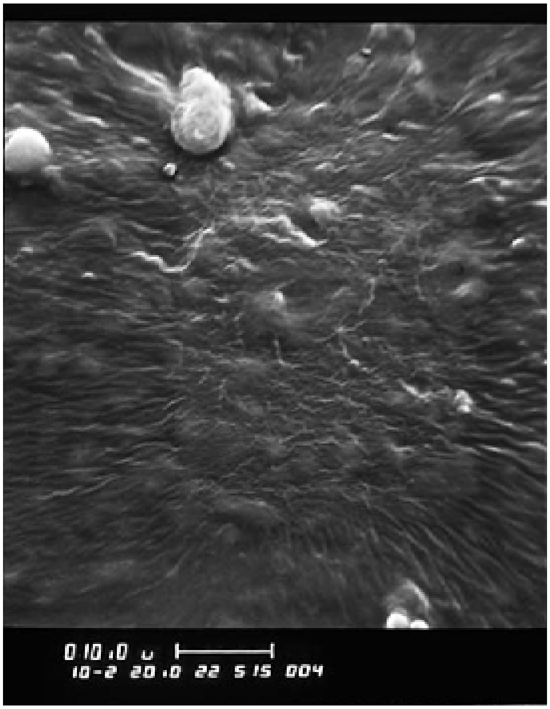


Figure 1.28

Scanning electron micrograph of the surface of a proprietary varnish provided by some manufacturers for sealing Type II.1 glass-ionomers. Note that the surface is relatively porous and there is likely to be considerable water transport through it. Original magnification × 1000.

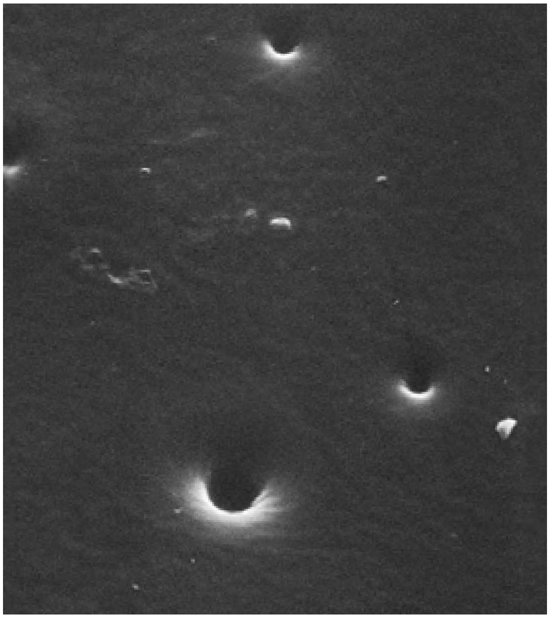


Figure 1.29

Scanning electron micrograph of single-component, very-low-viscosity, light-activated resin bonding agent spread over the surface of a glass-ionomer. Note the relative lack of porosity. Original magnification × 1000.

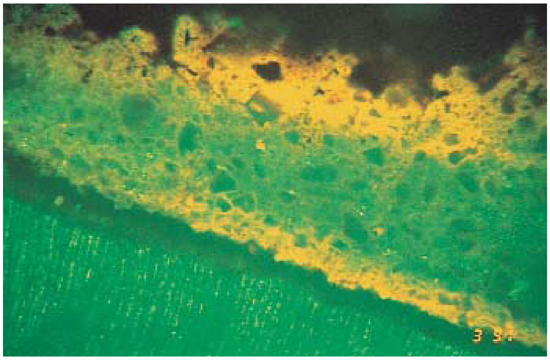


Figure 1.30

A confocal optical microscope study of a section through a glass-ionomer restoration that has not been protected during setting and was subsequently soaked in rhodamine B dye solution. Note that the cement has lifted off the dentine and there is severe degradation of the surface, with penetration of the rhodamine dye to the full depth of the glass-ionomer. (Courtesy of Dr TF Watson.)

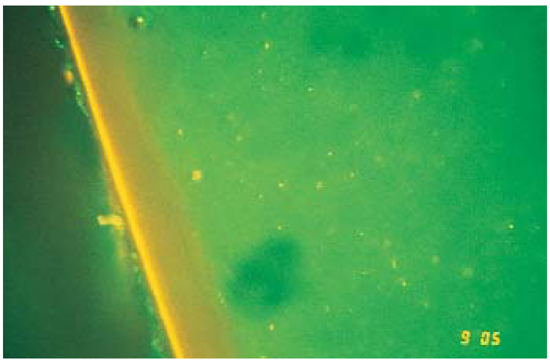


Figure 1.31

A confocal optical microscope study of a glass-ionomer (on the right of the illustration) which has been sealed with a very-low-viscosity, light-activated resin sealant containing maleic acid (yellow band on the left of the illustration – the bright yellow line is the oxygen-inhibited layer on the surface of the resin). Note the excellent adaptation of the seal and the complete integrity of the glass-ionomer. (Courtesy of Dr TF Watson.)

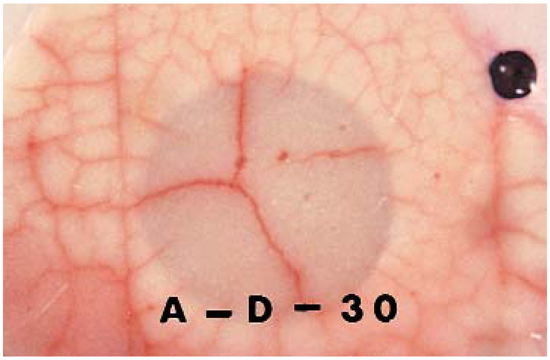


Figure 1.32

A laboratory specimen of ASPA that has been allowed to dehydrate on the bench for 30 minutes without any protection. It was then placed into a dye to reveal the cracks that had developed.

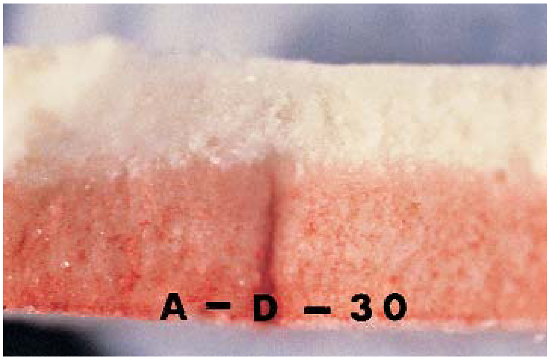


Figure 1.33

The same specimen has now been dismantled and allowed to fall apart. Note that the cracks penetrated almost the full thickness of the glass-ionomer.

therefore a better seal. Bonding agents that need to be premixed and contain an evaporative vehicle to reduce their viscosity will not be effective, because they are likely to be porous when set, thus allowing water exchange through the resin film. The same applies to chemically activated bonding agents, which, of course, require hand-mixing, with the consequent potential for incorporation of air bubbles and porosities.

It has been shown that the layer of bonding resin will remain on the surface of the restoration for some time, depending upon the vigour of the patient's brushing routine. Using a specially prepared low-viscosity resin bond containing a fluorescent dye, specimens have been monitored for as long as 6 weeks, and have shown a reasonable quantity of resin still in place on the cement. In view of the prolonged chemical maturation that occurs with glass-ionomers, the continued presence of the resin is desirable. It could be argued that this layer will inhibit the release of the fluoride; but, as it does not last for long, it is suggested that this is of less importance than the development of the full physical and aesthetic properties.

Some manufacturers maintain that their Type II.1 auto cure glass-ionomer can be contoured and polished at approximately 10–15 minutes after placement. Certainly, the cement will have achieved a degree of set such that polishing can be carried out, but only at the sacrifice of translucency and aesthetics. Both water uptake and water loss within the first 24 hours will downgrade the physical properties and appearance of these materials, and it is well worth while delaying the final finish for at least one day – preferably one week – if optimum results are required (Figures 1.34–1.49).

It should be noted that if a new restoration (less than 6 months old) is to be exposed to dehydration for longer than a few minutes, it is desirable to protect it again with a further layer of unfilled resin bond. After 6 months, the cement is generally mature enough to withstand such stress (Figure 1.41). The only problem arising from the use of such a long-lasting sealant is that an artificial overhang may be created or, with a

Figure 1.34

ASPA restorations were placed on the labial of both upper central incisors and copal varnish was painted over them in an attempt to retain the water balance because this was the recommended routine for silicate cements. When the patient presented for recall at six months it was apparent that the seal was not effective. Note the cracks and lack of translucency.

Figure 1.35

Glass-ionomer restorations on the labial surface of both upper-central incisors. The restoration on the left central was placed 2 years prior to the right central and was protected with a proprietary varnish. Note, following gentle dehydration, the white defect on the left central. The restoration on the right central was properly protected with a low-viscosity light-activated resin seal.

Figure 1.36

This photograph of the same restorations as are shown in Figure 1.35 was taken about 5 years later. When the restorations were lightly dried off the defect in the left central was more pronounced, so it was polished back a little to determine how deep the defect penetrated. Note that the defect is worse in the deeper levels. The restoration in the right-central incisor was protected at insertion with a light-activated resin bond and remains unaffected by dehydration.

Figure 1.37

Labial erosion lesions on the two upper-central incisors before treatment.

Figure 1.38

The above lesions were restored with an old-style Type II.1 glass-ionomer 5 years prior to this photograph, and were covered at insertion with copal varnish only. They appear to have been both hydrated and dehydrated during placement procedures, and require replacement.

Figure 1.39

The restorations were replaced with an improved Type II.1 auto cure glass-ionomer and protected at insertion with a very-low-viscosity, light-activated resin bond. They had been in place for 2 years when photographed.

Figure 1.40

Three cervical restorations were placed on different occasions. The restoration in the upper-left canine was placed 2 years ago and was properly protected and remains satisfactory. The restorations in both the central and lateral incisors were allowed to dehydrate at the time of insertion. Subsequently the restoration in the lateral incisor suffered bulk failure, and there is a crack apparent in the central incisor.

Figure 1.41

Cervical restorations in the upper-left central, lateral and canine. The upper central restoration has been in place for over 1 year and was properly protected. The restoration in the canine was placed 6 months earlier and was regarded as mature. However, as the restoration was being placed in the lateral incisor, the glass-ionomer in the canine dehydrated on the surface after approximately 10 minutes' exposure to air, showing that even at 6 months it was not completely mature.

Figure 1.42

A cervical restoration was placed in the upper-left first bicuspid one week ago and protected with a generous coat of bonding resin. There were small projections of resin left at the gingival margin, which led to a limited area of inflammation in the gingival tissue.

Figure 1.43

An old cervical composite resin restoration shows marginal leakage and accumulation of mature plaque. It requires replacement.

Figure 1.44

The same patient as shown in Figure 1.43. The cervical restoration on the upper-left canine immediately after replacement with a Type II.1 auto cure glass-ionomer and protection with a low-viscosity resin bond. Note the relative lack of translucency.

Figure 1.45

The same restoration, following polishing, 1 week after placement. There is a notable improvement in colour match and translucency, as the glass-ionomer has matured.

Figure 1.46

The same restoration photographed 15 years after placement. Note the lack of wear or further erosion. The colour change results from the patient's teeth maturing over that time period.

Figure 1.47

Cervical erosion lesions in the upper-left canine and first and second bicuspids were restored 5 years previously and protected with a resin-bonding agent. The restorations have not been polished at all and have retained the original surface from the matrix. They have been lightly air-dried, so that it is apparent that, even though a finish line was not cut in the enamel along the incisal/occlusal margin, the excess 'flash' remains intact.

Figure 1.48

Cervical glass-ionomer restorations in a group of upper anteriors, extending from the left-central incisor to the right canine, photographed about 4 years after placement, showing complete maturity and stability.

Figure 1.49

The same restorations as are shown in Figure 1.48 approximately 12 years after placement.

proximal restoration, the contact area may be closed by the resin. Both situations should be anticipated, and appropriate precautions should be taken. An overhang can be removed at the time of placement by using a sharp blade to cut away from the restoration towards the tooth (Figure 1.42). A closed contact can be re-opened later at the polishing appointment, if the patient has been unable to remove the resin. Mostly, the patient will succeed in restoring freedom.

The use of this same low-viscosity resin sealant over a newly placed resin-modified material is recommended to control water balance in the early stages, because the acid–base setting reaction may not be fully protected by the inclusion of the HEMA. In addition, the surface of the new restoration will be rather porous and slightly rough following contouring and polishing, and the low-viscosity resin will seal it and make the restoration smoother. The resin-modified materials also remain subject to dehydration for some weeks after placement; so, if it is necessary to expose a restoration to air for any length of time, it is wise to seal it with the same resin bond.

It has been suggested in the past that it is necessary to cut a shallow finish line along the incisal/occlusal margin of a cervical erosion lesion, because the cement is likely to 'ditch' along that margin if left in thin section. However, provided the cement is protected, as suggested, with a completely waterproof sealant, and is thus allowed to mature fully, the cement will survive satisfactorily, even though in thin section (Figure 1.47).

The chemistry of the fast-setting conventional glass-ionomers has been modified to the extent that they are resistant to water uptake within 5 minutes of the start of mix. It has been shown, in fact, that their physical properties will be enhanced by about 10–15% if they are exposed to water after the first ten minutes (Leirskar et al, forthcoming). However, they are still subject to dehydration for up to 2 weeks after placement. If left exposed for 10 minutes, they will visibly crack and craze, and attachment to enamel and dentine will fail. If, for example, a quadrant of cavities has been exposed under rubber dam and a glass-ionomer is to be used as a lining, the teeth should be restored one at a time. The lining should be placed in the first cavity and, as soon as it is set, covered with the final restorative material. If a Type II.2 material is to be used as the restorative material then it should be protected against dehydration with an unfilled resin bond while the remaining restorations are being placed. Once the cement is covered or immersed in saliva, it is safe from further dehydration.

The corollary to this rapid setting mechanism is that a Type II.2 restoration can be completed all the way to a final polish, beginning 7 minutes after the start of mix. Once the initial set is achieved, it can be contoured and polished to a very fine surface, using ultra-fine diamonds followed by graded rubber polishing points under air/water spray, taking care not to dehydrate it (see Box B, page 40).

Adhesion to enamel and dentine

A diffusion-based adhesion can be developed between the glass-ionomers and both dentine and enamel and this is unique to these materials (Aboush & Jenkins 1986; Lin et al, 1992;

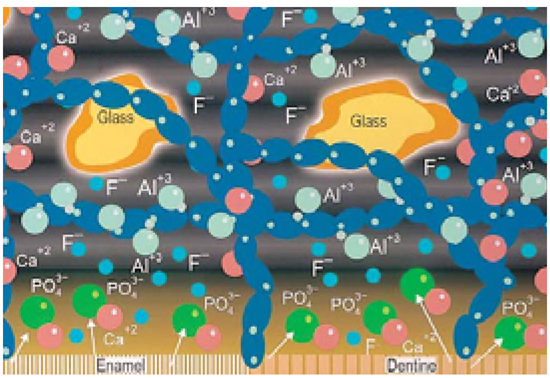


Figure 1.50

A theoretical diagram showing the development of the ion exchange between the glass-ionomer and the tooth surface. Note that the poly(alkenoic acid) chains actually penetrate the surface of both enamel and dentine and displace phosphate ions, releasing them into the cement. Each phosphate ion takes with it a calcium ion to maintain electrolytic balance, thus leading to an ion-enriched layer at the interface. As the acid is buffered by the release of the ions the pH will rise and the interface will set as a new ion-enriched material between the tooth and the restoration. This ion-enriched layer shows clearly in the following illustrations.

Akinmade & Nicholson 1993; Akinmade 1994; Mount 1991) (Figure 1.50). Ngo et al (1997b) described an ion-exchange layer that is visible under the scanning electron microscope and represents the chemical union between the two. It is suggested that the poly(alkenoic acid) attacks and penetrates the tooth structure, displacing phosphate ions. To maintain electrolytic balance, it is necessary that each phosphate ion take with it a calcium ion. These are taken up into the cement adjacent to the tooth, leading to the development of an ion-enriched layer that is firmly bound to glass-ionomer on one side and both enamel and dentine on the other (Ferrari & Davidson 1998; Geiger & Weiner 1993). The strength of both the ion-enriched layer and its union to the tooth have yet to be measured (Hood et al, 1981).

The adhesion appears to be a dynamic phenomenon. The polymeric nature of the glass-ionomer ensures a multiplicity of bonds between substrate and cement so that, under clinical conditions, the scission of a single bond does not lead to failure, because the bond can re-form. This means that, even though the bond strengths appear to be low when compared with in vitro resin bonding techniques, they are much more durable in the clinical situation (Mount 1997).

Because of the relatively low tensile strength of the glass-ionomer, failure of the union will normally be cohesive within the cement rather than adhesive at the interface between the glass-ionomer and the tooth, so that the stronger the cement, the better the adhesion (Figures 1.51–1.59) (Glantz 1977). This presupposes,

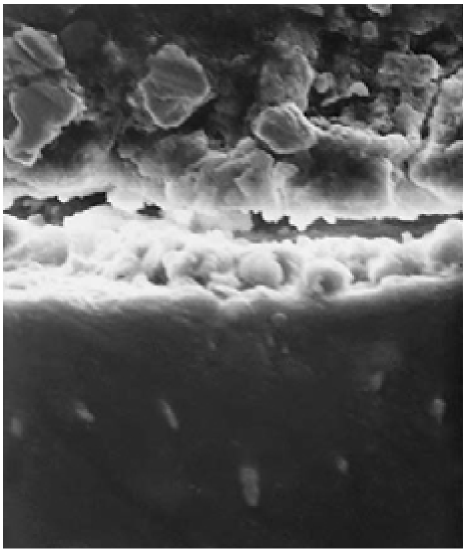


Figure 1.51

The restoration shown here was placed clinically, and the tooth was subsequently lost for periodontal reasons. The specimen was sectioned and dehydrated, and the scanning electron micrograph shows the ion-exchange layer between the glass-ionomer and the dentine. The layer is firmly adherent to the dentine, and separation has occurred as cohesive failure in the cement due to dehydration during preparation of the specimen for the SEM. Original magnification × 1000.

Figure 1.52

The same specimen as is shown in Figure 1.51. In this section part of the restoration has fallen off during dehydration and mounting. The scanning electron micrograph shows the ion-exchange layer remaining on the dentine after loss of the cement. Original magnification × 900.

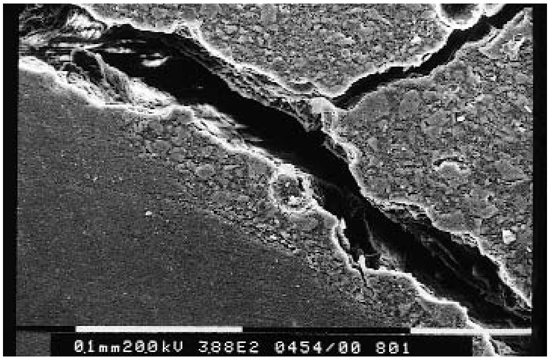


Figure 1.53

A similar specimen of a glass-ionomer restoration that has been sectioned and dehydrated for viewing under the SEM. There has been cohesive failure through the glass-ionomer, leaving some still attached to the tooth. Original magnification × 1000.

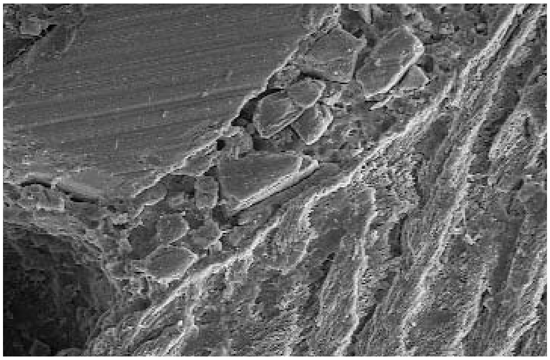


Figure 1.54

A glass-ionomer restoration has been placed in vitro and then sectioned and prepared for viewing under the SEM with a cryo-vac stage. Under these circumstances the specimen is deep frozen and the water balance is therefore maintained and the material will not crack. The surface has been polished and lightly etched to remove the smear layer. Note the ion-exchange layer at the interface. Original magnification × 1000.

Figure 1.55

The same specimen as is shown in Figure 1.54 demonstrates that the ion-exchange layer is more acid-resistant than both the glass-ionomer and the enamel. Original magnification × 10 000.

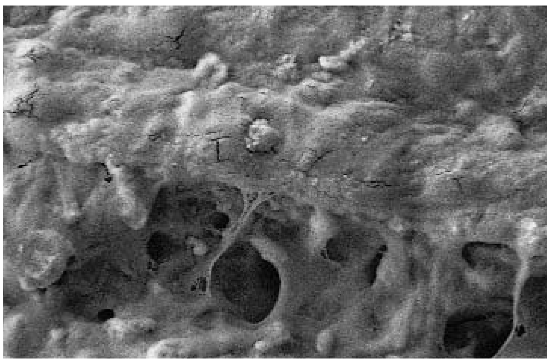


Figure 1.56

The area circled in Figure 1.55 is shown here at a higher magnification still. Original magnification × 22 000.

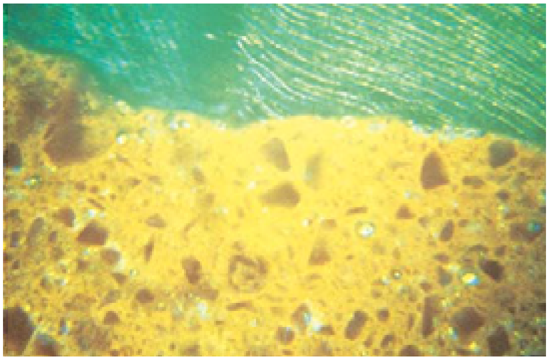


Figure 1.57

The union between glass-ionomer and both enamel and dentine examined through a confocal optical microscope. This technique does not require dehydration of the specimen before viewing, and therefore there are no artefacts present such as occur when preparing a specimen for viewing under an SEM. Note the intimate union between the three materials: enamel top left, dentine top right and glass-ionomer below. (Courtesy of Dr TF Watson.)

Figure 1.58

This scanning electron micrograph shows a section through a restoration that was placed in a deciduous molar, which was harvested at the time it was exfoliated. The section is similar to that shown in Figure 1.57, except that this was recorded under the SEM and therefore shows the usual cracks arising from the dehydration. Note that part of the crack goes through the enamel. Original magnification × 1000.

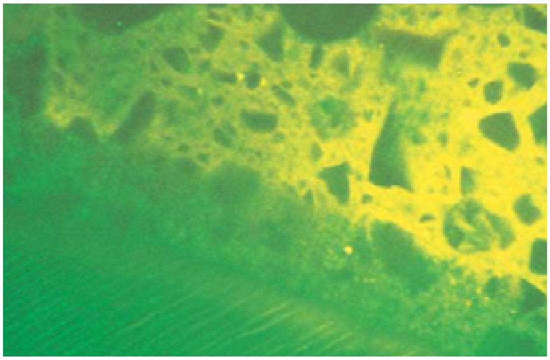


Figure 1.59

The union between glass-ionomer and dentine viewed under a confocal optical microscope. Rhodamine B was added to the water used to rehydrate the cement. Examination of the interface between the cement and the dentine now reveals fluorescent dye uptake into both the dentine and the cement, possibly confirming the ion exchange between the two. (Courtesy of Dr TF Watson.)

however, that the interface is clear of debris such as saliva, pellicle, plaque, blood and other contaminants (Figures 1.60–1.63). In the clinical situation this can be achieved by conditioning the cavity surface with a brief application of 10% poly(acrylic acid) (Aboush & Jenkins 1987). This is a relatively mild acid that will dissolve the smear layer within 10–15 seconds, although if left for longer than 20 seconds, it is likely to begin to demineralize remaining dentine and enamel and open up dentinal tubules. There are two additional advantages in using this particular material for conditioning the dentine. Firstly, since it is the same acid that is utilized in the glass-ionomer itself, any residue inadvertently left behind will not interfere in the setting reaction. Secondly, it will modify the surface tension and therefore enhance the wetability of the tooth surface. This leads to pre-activation of the calcium and phosphate ions in the tooth

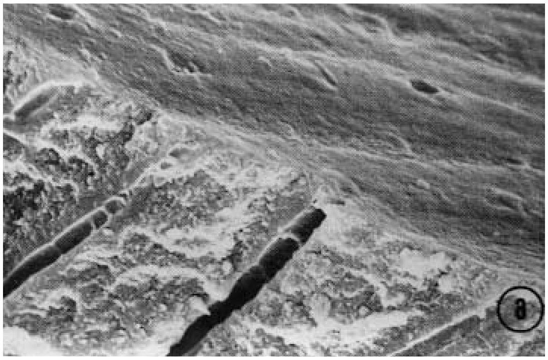


Figure 1.60

A fractured specimen showing a cross-section of the smear layer on the surface of a cavity following preparation. Original magnification × 1000.

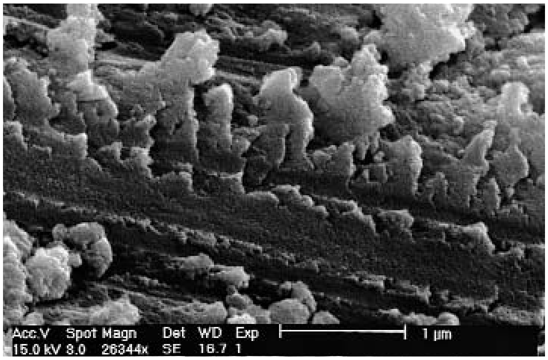


Figure 1.61

The smear layer at higher magnification, showing that it is a complex material that will only be an interference to the development of the ion exchange layer if it is left behind. Original magnification × 26 000.

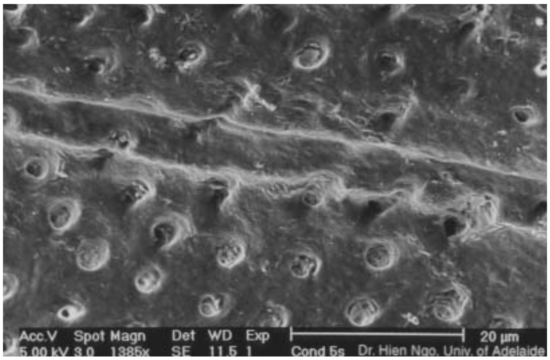


Figure 1.62

Scanning electron micrograph showing the surface of the dentine after a 10–15 second application of 10% poly(acrylic acid). Note that many of the dentine tubules are still occluded, but the surface is relatively clean. Original magnification × 800.

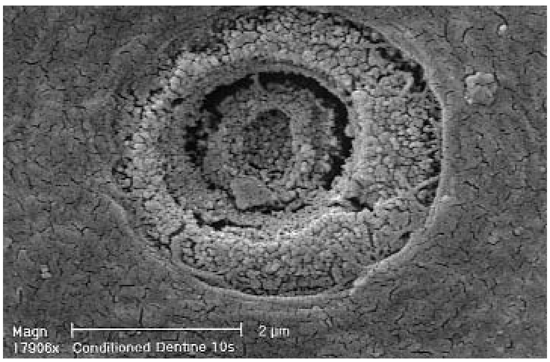


Figure 1.63

Scanning electron micrograph in the cryo-vac stage showing a single dentine tubule following conditioning for 10 seconds with 10% polyacrylic acid. Note that the tubule is still partly blocked up with debris and there will therefore be a limited dentine fluid flow. Original magnification × 18 000.

Figure 1.64

Cleaning an erosion lesion with a slurry of pumice in water. It is suggested that this is a good method of cleaning an erosion lesion prior to conditioning. Take care not to abrade the gingival tissue, because any bleeding will make it more difficult to maintain a clean surface during placement of the restoration.

Figure 1.65

Following cleaning with pumice and water condition the surface with 10% poly(acrylic acid) for 10 seconds only. The area should then be washed thoroughly and dried lightly without dehydrating it.

structure, rendering them more available for ion exchange with the glass-ionomer (Wilson and McLean 1988).

If chemical union is to be relied upon to retain the restoration in a cervical erosion lesion, it is recommended that the surface of the tooth be cleaned first with a slurry of pumice and water (Figure 1.64). Note that most proprietary polishing pastes will leave a smear layer behind, so plain pumice and water is preferred. The surface should now be conditioned with 10% poly(acrylic acid) for 10–15 seconds only (Figure 1.65). No cavity preparation is required. In fact, as adhesion is optimal between two smooth surfaces, any form of instrumentation likely to roughen the tooth surface is strictly contraindicated.

It should be noted that an alternative to removing the smear layer, particularly in a prepared cavity, is to apply a mineralizing solution such as 25% tannic acid or ferric chloride. These will tend to unite the smear layer to the underlying dentine and enamel and seal over dentinal tubules. This is the recommended technique when using glass-ionomer as a luting agent for full crowns. Considerable hydraulic pressure may be generated during the seating of crowns, and it is better to seal the tubules rather than open them up prior to placement.

Fluoride release

An apparent long-term fluoride release has always been regarded as one of the major advantages of the glass-ionomers. As with silicate cement, fluoride is used as a flux during the manufacture of the glass powder, and is thus incorporated within the glass, much of it in the form of extremely fine droplets. At the time of mixing, the surface of each powder particle will be dissolved by the poly(alkenoic acid), and there will be a considerable release of free fluoride, although some will remain in the matrix in the form of AlF. The initial peak may be quite high,

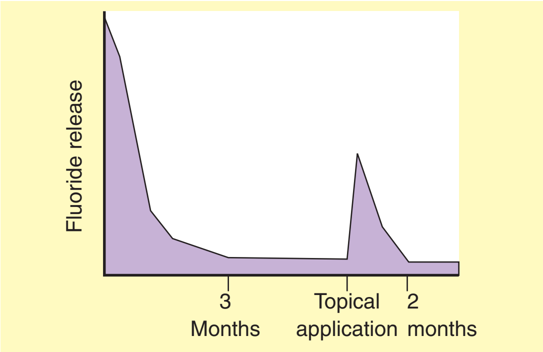


Figure 1.66

A graph showing the release of fluoride over time from an average glass-ionomer restoration (after Forsten). The steady level of release has now been observed over 8 years. Note that there is also the possibility for fluoride uptake following a professional topical fluoride application.

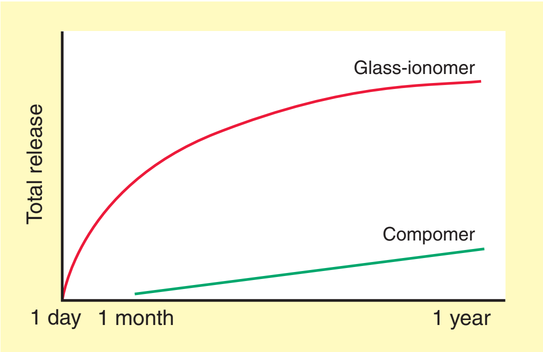


Figure 1.67

A graph comparing the fluoride release from a glass-ionomer and the release that can be expected from a compomer. Note the large discrepancy arising from the fact that a compomer is, in essence, a composite resin.

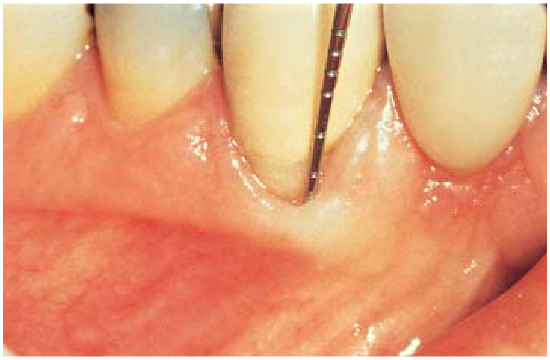


Figure 1.68

An erosion lesion at the gingival margin of the crown on the lower-right first bicuspid was repaired with glass-ionomer approximately 5 years ago. The gingival margin of the cement is 1 mm within the gingival crevice. Note the excellent condition of the gingival tissue lying over the glass-ionomer, because of the resistance to plaque build-up resulting from the continuing fluoride release.

Figure 1.69

Cervical glass-ionomer restorations on the lingual of the lower-right lateral and canine. There is an accumulation of calculus and plaque on the adjacent teeth. However, presumably because of the fluoride release, there is a relative lack of plaque accumulation on the glass-ionomer.

but the flow will decline fairly rapidly over the next 1–2 months, to finally stabilize at a low but steady level (Figures 1.66, 1.67). Maintenance of this level has now been monitored for at least eight years without a significant decline (Cranfield et al, 1982; Forsten 1993, 1998). The resin-modified materials appear to follow the same pattern, and this is to be expected, because the acid–base reaction is still the dominant part of the setting reaction of this material. Since the fluoride is not an integral part of the matrix of the cement, the fluoride release is not deleterious to its physical properties. It has been suggested that there is, in fact, a fluoride exchange available, with fluoride ions returning to the cement from external applications of fluoride at a later date if the fluoride gradient is in the right direction (Cranfield et al, 1982). Thus topical fluoride and the use of a fluoride toothpaste may provide a 'topping-up' effect (Figure 1.66). (See Chapter 2.)

The fluoride release from the outer surface of a restoration leads to a number of effects. Plaque is less likely to accumulate on the surface of the restoration because of the mild anti-bacterial effects of fluoride (Figures 1.68, 1.69). As the fluoride is released there appears to be a return of calcium and phosphate ions into the glass-ionomer to maintain electrolytic balance, and this leads to maturation and hardening of the surface (Nicholson et al, 1999). This may explain, at least in part, the increasing resistance to wear that is typical of the glass-ionomers. Finally, since there is no microleakage at the margin, there will be no development of wall lesions, and both tissue tolerance and colour stability will be of a very high order.

Physical properties

Work is in progress on improving the physical properties of glass-ionomers, and it is anticipated that the next generation will extend the clinical applications of this group of materials quite markedly (Mount 1999). Theoretically, flexural strength can be improved by the inclusion of a disperse phase, and this has been tried but is not yet clinically proven. Very fine silver spheres have been sintered to the surface of the powder particles to form a cermet, and this has improved abrasion resistance; but other properties are not greatly enhanced (McLean & Gasser 1985) (Figure 1.70).

The inclusion of additional resins, i.e. resin-modified materials, has led to an improvement in compressive and tensile strength, as demonstrated by the shear/punch test. The test suggests that the strength of the glass-ionomers is coming close to that of the micro-filled composite resins (see Figures 1.7–1.9). However, they are still not recommended for rebuilding a marginal ridge or an incisal corner.

The most recent modifications have been developed through the refinement of the processing of the glass frit. Care is now taken to select controlled grain size, with the removal of dust particles, and the powder is then subjected to further treatment to enhance the reactivity of the surface of the particles. There is also an increase in acid content and greater stability in the water balance. The result is conventional auto cure materials with even higher strengths than the resin-modified and with enhanced translucency and colour match. Whilst they do not quite match

Figure 1.70

Core build-ups using a cermet material on two upper-right bicuspids. There is still sufficient natural tooth structure left to accept the occlusal load that is expected to be placed on the final crown restorations, thus compensating for the relative lack of tensile strength in the cement.

the aesthetics of the original conventional Type II.1 restorative aesthetic materials, they are very acceptable for any situation where the aesthetic challenge is not too great. They are fast-set materials with increased surface hardness, early resistance to water uptake and a notable shortening of setting time. In fact some versions of these are designed to set very fast indeed.

Variations to the basic constituents of the glass-ionomers are being subjected to experimentation, and increases in physical properties may result. However, the essential elements of this group will always be the ion-exchange adhesion available between the glass-ionomer and tooth structure through the presence of poly(alkenoic acid), as well as the continuing ion exchange. Inclusions in the formula that reduce the effectiveness of the poly(alkenoic acid) or, indeed, eliminate the acid entirely will remove that material from this highly successful group. The alternative tooth-coloured materials discussed on pages 10 and 11 fall into this category, and, in spite of apparently greater physical properties in some of the materials, they should not be confused with true glass-ionomers.

Fracture resistance

At the present stage of development, the physical strength of the material is sufficient to withstand moderate occlusal load, provided a restoration is well supported by surrounding tooth structure. It is not recommended for rebuilding cusps or marginal ridges to any extent, particularly in the patient who is likely to exert heavy occlusal load. Resistance to tensile and shear stress is such that it should not be relied upon as sole support for a crown. The Type II.2 restorative version is valuable as a core build-up because it is possible to proceed immediately to the final preparation of the tooth. But the glass-ionomer requires considerable support itself from remaining surrounding tooth structure. This means that, for a core build-up, there must be a cuff of at least 2–3 mm of tooth structure around the cervical margin to provide the essential support for the crown (Figure 1.70). However, it can be regarded as ideal for the modern minimal-intervention type of conservative operative dentistry, because it will have adequate support from remaining tooth structure and its inherent brittleness will be of no consequence (see Chapter 7).

Resistance to shear stress is not good. For example, although it has an excellent record for the restoration of erosion lesions, the material will not be retained on the labial surface of lower anterior teeth that have been abraded through a deep overbite and then suffered further erosion. Although there is room for the cement without interfering with the occlusion, the shear stresses are too great (Figure 1.71).

Abrasion resistance

The degradation of the material in the oral cavity has yet to be studied fully, but reports on longevity suggest that a well-placed glass-ionomer will withstand heavy abrasion better than remaining tooth structure, provided that the powder–liquid ratio is high enough (Mount 1986) (Figures 1.72,

Figure 1.71

Three lower anterior teeth in a patient with a very deep overbite. Considerable abrasion has removed all the enamel, and subsequently the dentine has been subjected to erosion. As there was sufficient space available, glass-ionomer restorations were placed on all three, but they all failed because of the extreme shear stresses. The only surviving glass-ionomer is the gingival section on the canine, which was beyond the incisal edge of the opposing canine and therefore relatively free of direct stress.

Figure 1.72

Cervical ASPA restoration in an upper-left canine, 12 years after placement. There is further erosion in the tooth structure beyond the restoration. Despite the rather poor-quality cement, it has maintained its contours well.

Figure 1.73

The same restoration as is shown in Figure 1.72. The restorations in the central and lateral incisors have been in place for 4 years.

Figure 1.74

The cervical restorations on the upper-right lateral and canine have been in place for 14 years and show little sign of wear. (See Chapter 4, Figures 4.2–4.9)

1.73). It has been shown that the wear resistance in the first week or two prior to maturation is rather low, but thereafter improves steadily. It would appear that this comes about because of the continuing ion exchange on the surface of the restoration. As the fluoride ions are released they will be steadily replaced by hydroxyl and phosphate ions to maintain correct electrolytic balance. Over time it appears that the entire surface to some depth will mature, and clinical observation shows that restorations last very well (Figure 1.74).

The presence of finely powdered silver particles on the surface of the glass particles, as in the Type II.2 restorative cermet cement, will increase abrasion resistance to the stage where it is similar to that of amalgam or composite resin (Figure 1.75). In the laboratory the resin-modified materials appear to demonstrate an

Figure 1.75

Part of the lingual cusp of the lower molar was repaired in an aging patient using a cermet rather than attempting to replace the entire restoration. Seven years later the repair shows little sign of wear and appears to be stable.

initial swelling followed by a slightly lowered resistance to abrasion, probably because of the water uptake.

Dimensional stability

The auto cure materials show a limited degree of setting shrinkage (up to 2–3%) over a short period of time. However, because it is a chemical set, the shrinkage will occur inwards toward the cavity floor – in part because of the relatively higher temperature of the cavity floor – and the ion-exchange union with the tooth structure will not be subjected to undue stress. Subsequent water uptake will compensate for the shrinkage, and the restoration will stabilize over the week after placement to the extent that dimensional change will be neutralized.

The situation is modified by the inclusion of additional resins in the resin-modified materials, particularly the inclusion of HEMA, which is very hydrophilic. The acid–base reaction will begin as the glass-ionomer is mixed, and the ion-exchange mechanism with the tooth will commence immediately it is placed into the cavity. The application of the activator light, however, will bring about an immediate polymerization in the resin component of the cement, with a shrinkage up to 1%. Since the extra resins represent no more than 5% of the total restoration, the shrinkage is not expected to direct undue stress on to the ion-exchange union with the tooth that is still in the process of development. The acid–base reaction will then continue at a somewhat reduced rate, and the 'dark cure' phase of the setting mechanism of the additional resins will reach completion within a short period of time. The final auto cure component will lead to a small degree of shrinkage; but this too will be slow, and will be compensated by water uptake over a short period.

The early resin-modified lining and luting cements had a high HEMA content and showed a considerable water uptake over 90 days, with an increase in volume and a reduction in physical properties. The restorative resin-modified materials, however, show a very small water uptake over the same period of time and maintain their physical strength very well. The increase in volume is of the order of 3%, and seems to be of little clinical significance. The only possible complication may arise when building an extensive core with glass-ionomer. It is suggested that this be allowed to mature before taking final impressions, in case there is sufficient expansion to introduce an error.

Radiopacity

It is desirable that an interproximal restoration in a posterior tooth be able to be differentiated radiographically from dentine or further caries, so that changes can be reliably monitored. The glass-ionomers can be made radiopaque through the selection of an appropriate glass containing either strontium or lanthanum, or the inclusion of radiopacifiers such as barium sulphate or metals such as silver. Generally the radiopacity of both the modern auto cure and the resin-modified materials comes from the glass, and comfortably

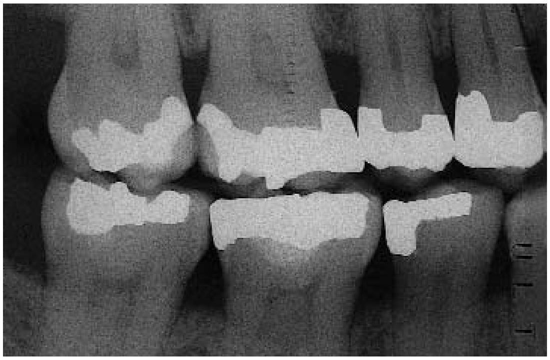


Figure 1.76

Tunnel restorations in the upper-right first and second molars using a cermet glass-ionomer show radiopacity very similar to that of amalgam.

Figure 1.77

A bitewing radiograph of resin-modified glass-ionomer restorations in upper and lower first deciduous molars, showing radiographic contrast with tooth structure sufficient to allow future monitoring of the restoration.

exceeds that of dentine (Figures 1.76 and 1.77). The colour and translucency are not affected, so they can be placed universally even if radiographic monitoring is not appropriate.

The original auto cure Type II.1 aesthetic restorative materials are generally radiolucent, and the inclusion of radiopacifiers tends to modify the colour and translucency, so that they are not recommended for the restoration of cavities where radiographic monitoring is required.

Polishing

The process of producing a fine surface on any restorative material is one of reducing the depth of the scratches that have developed during recontouring. With the glass-ionomers, the smoothest surface will be that developed under a soft tin matrix or a mylar strip. The surface will be mildly porous and matrix-rich, with very few glass particles showing and, prior to full maturity, very susceptible to damage. When placing a Type II.1 restorative aesthetic restoration, particularly very early in the life of the restoration, any reshaping should be kept to a minimum, and the surface developed by the matrix should be maintained.

All the fast-setting glass-ionomers, including the resin-modified materials, can be trimmed and contoured as soon as they are set. Gross contour can be modified using a sharp blade, moving from the restoration to the tooth to avoid stressing the newly forming ion-exchange adhesion layer. Any additional contouring should be carried out with fine diamond rotary instruments, beginning at intermediate high speed (20 000–40 000 revolutions/min) and reducing the speed with the finer instruments. Always work under air/water spray to avoid dehydration.

Initially, particularly with the resin-modified materials, use fine-graded diamond polishing burs, beginning with the relatively coarse stones (25 μ grit size) and changing to finer ones (5–10 μ grit size) for a better finish. The ultimate surface can

BOX B POLISHING METHODS

Type II.1 restorative aesthetic

Resin-modified

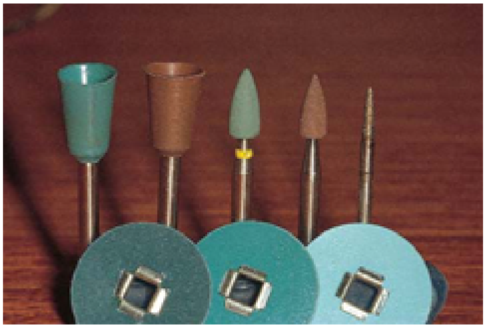
- Contour and polish immediately after light-activation, working from restoration to tooth only.
- Begin with fine polishing diamonds at intermediate high speed (40 000 revolutions/min) under air/water spray.
- Continue with ever-finer diamonds at lower speeds, still under air/water spray.
- Finally complete using aluminium oxide graded polishing discs at slow speed under air/water spray; then seal with a low-viscosity resin glaze.

Auto cure

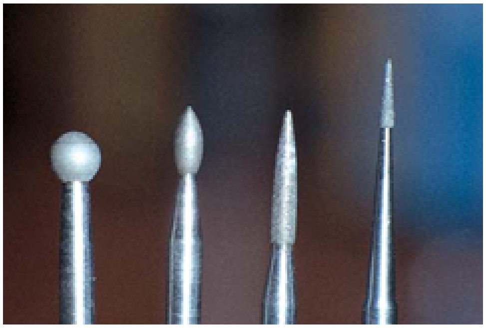
- Because of the slow-setting chemistry, do not attempt to contour or polish the restoration for at least 24 hours. Only if essential, use a sharp blade to reduce gross contour at the time of insertion.
- After 24 hours minimum, gross contour can be achieved with very fine sintered diamonds under air/water spray at 20 000 revs/min.
- Refine the surface with graded rubber polishing points and cups at 5000 revs/min under air/water spray.
- Finish to a gloss with graded polishing discs at 3000 revs/min under air/water spray; then seal with a low-viscosity resin glaze.

Type II.2 restorative

- Because of the rapid-setting chemistry, these materials can be contoured and polished, beginning at 6 minutes from the start of mix.
- Gross contour can be achieved with very fine sintered diamonds under air/water spray at 20 000 revs/min.
- Refine the surface with graded rubber polishing points and cups at 5000 revs/min under air/water spray.
- Interproximal surfaces can be contoured and polished with the Profin Directional System equipment using diamond or polishing blades.



A selection of polishing cups and points, finishing and polishing discs.



A selection of graded fine diamond polishing stones. They range from moderately coarse to extra fine, allowing for rapid development of a fine surface.

be developed with fine-graded aluminium oxide discs, still under air/water spray. The quality of the finished surface will depend in part on the size of glass particles in the cement and in part on the degree of porosity. Inevitably, the cement will be porous, because it is a two-part mixed material. Generally capsulated machine-mixed cements show many fine porosities, while hand-mixed ones have fewer but larger defects. Application of a very-low-viscosity resin glaze over the final surface will fill the porosities and leave an even better surface; but care must be taken not to leave an excess of glaze, so forming a ledge or overhang.

2 Biological potential of glass-ionomers

Hient Ngo

Up to this time almost all the restorative materials used in dentistry have been biologically inert and have shown no activity in relation to the tooth structure they replace. It has been known for many years that amalgam corrodes in oral fluids and that the corrosion products closed the interface. It was also shown that silicate cement released fluoride ions, and that these appeared to be taken up into the surrounding tooth structure and reduced the risk of further caries.

When the glass-ionomers were first released in 1976 it was noted that these also released fluoride ions in the same manner and, for that and other reasons, they rapidly replaced the silicates. As long as the profession concentrated on trying to eliminate caries through a surgical approach there was not a great deal of interest in the release of these and other ions. However, there were researchers such as Massler, Fusayama and Brannstrom writing detailed reports on the science of demineralization and remineralization of tooth structure and the theoretical value of ion exchange as early as the 1960s.

Recent investigations have looked more deeply into the exchange of ions both out of the tooth structure and back into it from a variety of sources. The saliva is, of course, the most important element from this point of view, because in a healthy patient it is a super-saturated solution in relation to both calcium and phosphate ions. However, it is now apparent that glass-ionomer is also a rich source of ions, and it is possible to trace the exchange from the cement both into and out of tooth structure as well as other skeletal structures. It is quite apparent that it is now possible to think in terms of remineralizing and healing diseased enamel and dentine with glass-ionomer as part of the equation. There is already considerable clinical evidence of the value of these techniques, and clearly they open the way to far more conservative methods of dealing with the ravages of caries.

The following paragraphs discuss the significant elements of the understanding of the bioactivity of glass-ionomer and its relevance to healing the carious lesion. This information needs to be kept in perspective with the understanding that no restoration or restorative material will be proof against further caries. As caries is a bacterial disease, it is only possible to control it by modification of the bacterial flora, and all dental treatment must be predicated upon active treatment to achieve this.

The significance of water in glass-ionomer

Probably the most important underlying factor in relation to the glass-ionomers is that they are a water-based material and that water plays a significant part in their setting reaction as well as in their final structure. Water is the reaction medium into which the cement-forming cations – calcium and aluminium – are leached and within which they are transported to react with the polyacid to form a polyacrylate matrix. It also serves to hydrate the siliceous hydrogel that surrounds the glass particles (Figure 2.1) and the metal polyacrylate salts as they form the matrix. It is therefore an essential part of the cement structure, and if water is lost by desiccation while it is setting the reaction will be affected.

Once the material is set the water content is arbitrarily classified as either 'loosely bound water' or 'tightly bound water'. The loosely bound water can be lost quite readily in the early

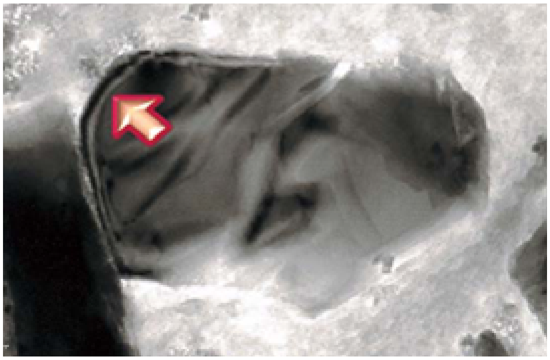


Figure 2.1

TEM micrograph of a glass-ionomer showing an ultra-thin sectioned glass particle with evidence of the hydrogel phase surrounding it (red arrow).

stages if the cement is left exposed to air; but the tightly bound water cannot be removed at all. The latter is associated with the hydration shell of the cation–polyacrylate bond, particularly that of aluminium; and, to a degree, to some of the silica gel water as well.

As the material ages the ratio of tightly bound to loosely bound water increases, and along with this increase the strength and modulus increases and the plasticity decreases. However, the loosely bound water remains labile and easily lost in the early stages before maturation. Loss of this water will result in shrinkage, leading rapidly to cracking and undue stress on the ion-exchange adhesion that will be rapidly forming in the early phases after placement. The period of vulnerability to water loss and water uptake will vary with the material, and considerable research has been undertaken to minimize the problem. Most of the present materials, and particularly the resin-modified glass-ionomers, will be resistant to water uptake within minutes of placement; but they all remain susceptible to water loss for anything up to two weeks.

Probably the one most important factor arising through these materials being water-based lies in the basic chemical principle that it is only possible to have ion mobility in the presence of water. Obviously ion mobility is essential for both demineralization and remineralization of tooth structure, so that totally anhydrous materials can play no part in these activities. However, glass-ionomer contains fluoride, calcium, strontium and aluminium ions. All of these are capable of migration, and can therefore be harnessed, to some degree, to assist in the healing process.

The ionic components of glass-ionomer

As has been previously discussed, the glass used in the manufacture of a glass-ionomer is made up from a series of elements, and the constituents vary from one material to another. It must be noted that calcium has always in the past been regarded as a significant element in any glass-ionomer. However, there are a number of materials now that contain strontium in place of calcium, mainly because this will impart a degree of radiopacity to the resultant restoration. Owing to their similar polarity and atomic size these two elements are interchangeable in the composition of glass-ionomer as well as in the crystal lattice of hydroxyapatite. In other words, it is possible to develop a strontium hydroxyapatite instead of a calcium hydroxyapatite. This factor has facilitated research into remineralization to a considerable degree, because calcium lost through caries can be replaced by strontium from a glass-ionomer, and therefore traced readily into tooth structure and quantified quite accurately.

It is also interesting to note that there is some evidence that strontium has additional anticariogenic properties. According to the available epidemiological data the anticariogenic action of fluoride in the water supply is so overwhelming that the possible effect of other minerals is hard to detect. However, Curzon et al. (1970) reported on the caries-reducing effect of a high level of strontium in drinking water. He noted a reduction in DMFT that decreased nearly linearly with the strontium content in drinking water up to a level of about 10 ppm.

Several authors – Lagergren et al. (1957), Collin (1959), Sarver et al. (1961), and Heyligers et al. (1979) – were successful in synthesizing various forms of strontium phosphates and strontium-containing apatites. Driessens et al (1985) concluded that strontium fluoroapatite is much more stable than strontium hydroxyapatite. All this tends to confirm the hypothesis that strontium can participate effectively in the remineralization process.

Thus the following observations on the bioactivity of glass-ionomer must be read with the understanding that calcium and strontium are essentially interchangeable in this context, and a number of modern glass-ionomers are based on a strontium glass.

The essential elements in a glass-ionomer include calcium (strontium), aluminium, silica and fluoride, and all of these species can be released from the glass following immersion in a polyalkenoic acid. The newly released calcium ions will become attached to the polyacrylic acid chains very rapidly, leading to an early set of the cement, and these will be followed quite quickly by the aluminium ions. Subsequently the silica ions will form a siliceous hydrogel around the remaining glass particles. However, because of the presence of water, all these ions will remain available for transfer from the matrix into the surrounding environment, and it has been shown that there is a constant interchange between the set cement, the saliva and tooth structure.

It is well accepted that the release of fluoride ions from glass-ionomers is due to an exchange process. During periods when their immediate environment is rich in fluoride the glass ionomers will take it up and store it for release back to the environment when the balance alters. The same can be said for the other ionic species present in the matrix. Figure 2.2 illustrates the release patterns of strontium, aluminium and fluoride at pH 6.5. Note that the level of strontium (calcium) ions released into the environment far exceeds that of the fluoride or aluminium ions. It is also apparent that the pattern of release responds to the level of acidity (Figure 2.3).

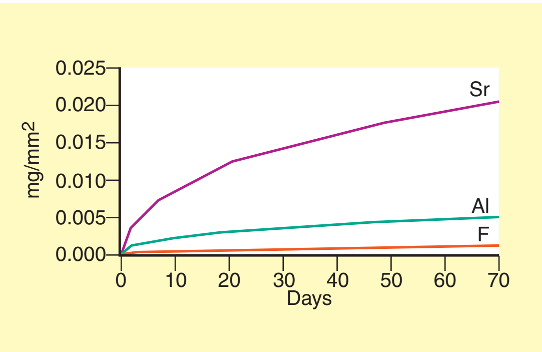


Figure 2.2

A chart showing the release of strontium, fluorine and aluminium from Fuji IX into deionized water at pH 6.5.

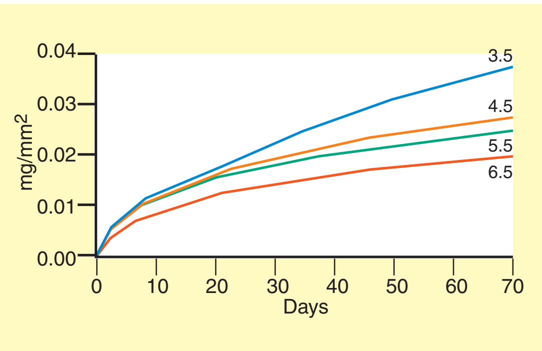


Figure 2.3

A chart showing that the release of strontium from Fuji IX into deionized water is dependent on pH. The lower the pH, the greater the release, and this is significant in the presence of high caries activity.

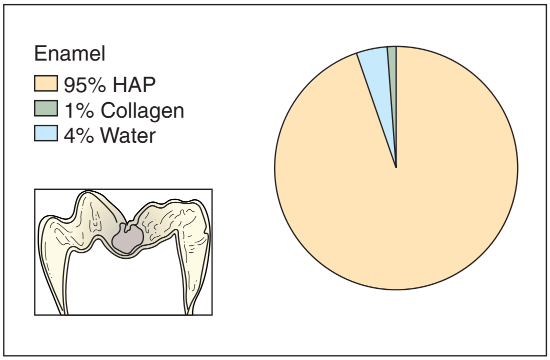
It is also clear that a high level of fluoride in the tooth structure is of less importance than a moderate level of fluoride in the surrounding oral fluid. Modern concepts of the mechanism of fluoride activity emphasize the significance of the maintenance of a continual low level of fluoride in the saliva to maintain control of enamel dissolution. In fact this approach is significantly more effective than a periodical topical application of a high-strength fluoride.

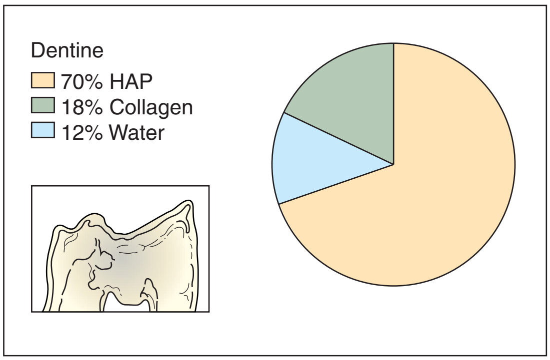
In order to understand how fluoride and other ions can interfere with caries development it is pertinent to clarify some fundamental aspects of the inorganic chemistry of the caries process. The following sections will therefore focus on details of the composition and characteristics of the hard dental tissues and on the principal chemical conditions that may lead to demineralization.

Mineral phase of enamel and dentine

The mineral phase in both enamel and dentine is composed mainly of hydroxyapatite, $Ca_{10}(PO_4)_6(OH)_2$. By weight it is 37% calcium, 52% phosphate and 3% hydroxyl, and these are identified as the essential elements of the apatite proper. Figures 2.4 and 2.5 illustrate the composition of enamel and dentine in terms of weight percentage. The organic matrix is negligible in enamel; but in dentine both water and organic matrix play an important role in maintaining its integrity. However, the significance of the water and organic phases on the permeability of enamel and dentine can be better appreciated when their contributions are considered in terms of volume percentage (Figures 2.6, 2.7). It is now apparent that both materials can be regarded as quite porous to migrating ions – particularly dentine, because 23% of its volume is occupied by water.

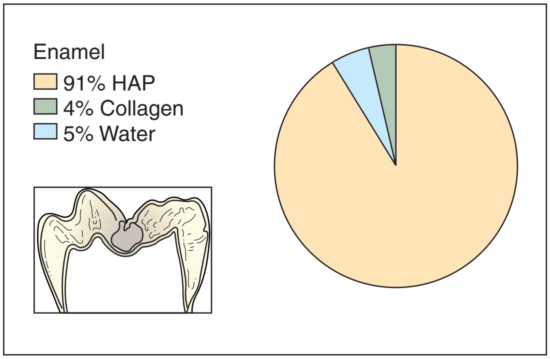
The enamel is composed almost entirely of hydroxyapatite, and each crystal of $Ca_{10}(PO_4)_6(OH)_2$ is surrounded by a layer of tightly bound water. The presence of this hydration shell shows that the crystal is electrically charged and can therefore attract ions that are able to play a part in remineralization. The

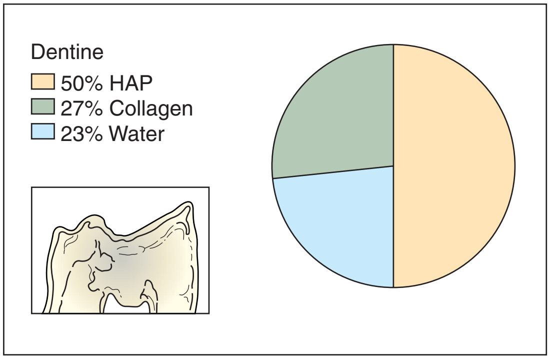




Figures 2.4 & 2.5

Pie charts showing the composition of enamel and dentine by weight. Note that there is a significant amount of water contained in both, as well as a reasonable quantity of collagen in the enamel.





Figures 2.6 & 2.7

Pie charts showing the relative contents of enamel and dentine by volume. Note the significant difference between the content by volume compared to the content by weight. This illustrates the porous nature of enamel and, especially dentine.

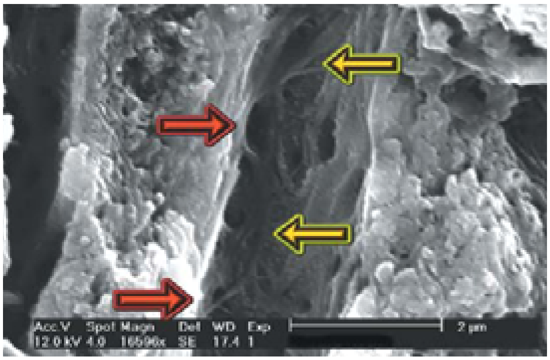


Figure 2.8

A split section through dentine showing the complexity of the dentine tubules and the lateral canals that join the tubules together and increase the potential for ion transfer. Note the dimensions of the specimen as shown by the space bar. The red arrows point to the openings of the lateral branches; the yellow arrows point to the collagen network.

remaining water fills the spaces between the rods, and these pores form the main diffusion pathway into and through the enamel.

Dentine contains 23% water by volume, and the water-filled pores form a diffusion pathway that is relatively minor compared with the intertubular lateral microtubules (Figure 2.8) and the dentinal tubules themselves.

As a result of the above, it is apparent that, in spite of external appearances, both enamel and dentine are porous and ion migration is quite possible. Acid can penetrate enamel, and ions can be displaced and removed to initiate the caries process. The outer apatite crystals will dissolve from the surface of the enamel rods and increase the level of porosity, thus facilitating acid transport and further demineralization. However, it is apparent that the opposite action is also possible, with ions returning along the same pathways, so that the enamel can remineralize and heal. This

cycle of demineralization followed closely by remineralization is constant in the normal oral environment, and it is only when the speed and level of demineralization becomes dominant that actual surface cavitation becomes possible. Generally the enamel rods are packed tightly together, and are to a degree self-supporting, and the pores in the enamel are not large enough to admit bacteria. This suggests that the lesion will need to be quite well advanced before the surface will disintegrate sufficiently to allow accumulation of bacterial plaque on the cavitated surface; and at this point the lesion becomes irreversible.

At all stages of the development of the lesion it is possible to reduce the level of acid attack and allow the remineralization cycle to become dominant again. In fact, if the bacteria can also be eliminated the process of remineralization can become quite vigorous. It is then a question of providing fluoride, calcium and phosphate ions at a sufficient level to ensure adequate repair and healing. The origin of these migrating ions is significant. They are generally available from the saliva; but they can also be derived from glass-ionomer. Their origin and destination are of considerable importance in this discussion.

Progress of the carious lesion

Conventionally, enamel caries and dentine caries are described as two independent entities. This convention is to some extent understandable, as the two tissues differ markedly from each other in terms both of embryonic origin and of composition and structure. The enamel is derived from the ectodermal component of the tooth germ, while the pulpo-dentinal complex is developed from the mesenchymal components.

The enamel is acellular, and cannot respond to injury, whereas the dentine is an integral part of a living and complex organ. Dentine and its cellular component, the odontoblasts, are all essential parts of the pulpo-dentinal organ, which possesses specific defence reactions to external insults. As described earlier, the enamel is microporous, and external stimuli, both chemical and physical, can pass through to reach the pulpo-dentinal organ long before the enamel surface is breached by cavitation.

The most common early defence reaction from the pulpo-dentinal organ is tubular sclerosis, that is, deposition of minerals within the dentinal tubules (Figure 2.9). Tubular sclerosis is a process that requires the participation of vital odontoblasts. There is an initial calcification of the odontoblast process, followed by mineralization of the peritubular space by hydroxyapatite and other mineral crystals. At a light microscopy level, the obturated tubules appear translucent, because the mineralization of the tubules makes the tissue more homogeneous, reducing the scattering of light rays passing through. Sclerotic dentine is often referred to as the ‘translucent zone’, and it must be assumed that this is an attempt by the body to wall off the lesion (Figure 2.10).

Once there is breakdown and cavitation of the enamel surface the demineralization process will move into its second phase. Mechanical forces during normal function, and also from careless probing, can initiate or speed up this breakdown. Actual invasion of bacteria into dentine tubules will not occur until there is direct exposure of

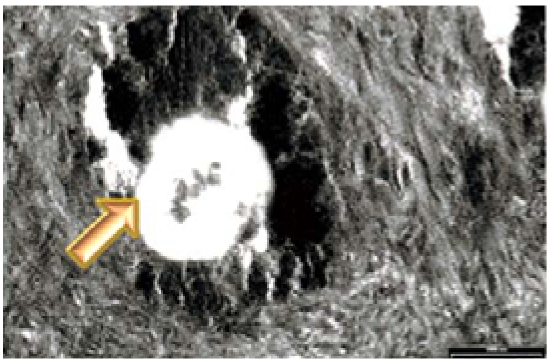


Figure 2.9

TEM micrograph of sclerotic dentine, showing the mineral plug (yellow arrow) deposited by the odontoblast process within the dentinal tubule to protect itself against an advancing carious lesion.

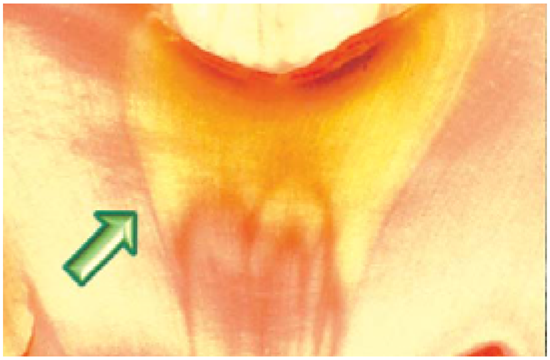


Figure 2.10

Cross-sectional view of an early carious lesion showing the translucent zone (green arrow) formed ahead of an advancing carious lesion. There has been considerable demineralization of both the enamel and the dentine immediately below the enamel. Below that there has been a degree of sclerosis, with some mineralization of the odontoblast processes as well as mineralization within the lateral canals, leading to the formation of the so-called 'translucent layer'. This is an attempt by the body to wall off the lesion.

dentine to the bacterial biomass accumulating in the enamel cavity.

Once the dentine is involved, the superficial layers will be destroyed by a combination of both acids and proteolytic enzymes. Beneath this zone, bacterial invasion of the tubules can be seen under light microscopy as isolated colonies of bacteria advancing ahead of the main bacterial biomass. There is no doubt that these colonies can contribute to the overall destruction; but in comparison to the biomass found on the floor of the cavity their activity is negligible. Once they are cut off from the rich external source of nutrient and sealed under a restoration, these isolated colonies will not be able to proliferate any further and will become dormant.

Fusayama et al. (1966) suggested that the bacterial invasion front will be a long way ahead of the discoloration and softening of the dentine. He also differentiated carious dentine into the first and second decalcified layers, and suggested that only the first layer should be removed during operative treatment. At about the same time, Massler (1967) named these the 'infected' and 'affected' layers. Subsequently Pitts (1983) and Mertz-Fairhurst et al. (1992) found that caries left under a properly sealed restoration will not progress. All of this suggests that the inner softened layer could well be regarded as being 'pre-carious' rather than actively carious, and this could modify the perceived need to remove all softened dentine.

This concept was reinforced by a clinical study wherein heavily carious first molars were restored following minimal caries removal, and a complete seal was achieved using a strontium-based high-strength glass-ionomer. The teeth were subsequently harvested, and it was found that both fluoride and strontium had penetrated through both the soft and discoloured dentine and become part of the normal apatite crystals beyond. Two distinct zones were identified, an outer layer of non-remineralizable dentine with minimal fluoride and strontium uptake, and a deeper zone that was well remineralized by these ions.

It was postulated that the collagen network in the non-remineralizable zone was totally devoid of mineral, and this lack of seeding sites prevented the uptake of any further mineral ions under clinical conditions. The remineralizable dentine still contained at least 20% by weight of mineral, so that the incoming apatite-forming elements, such as fluoride, calcium, strontium and phosphate, were able to be absorbed into this remaining mineral phase.

External ion exchange

The foregoing suggests that sealing a cavity and isolating the area from further bacterial activity can reverse the demineralization to such an extent that it is possible to heal a lesion. If the external surface of the crown is rendered smooth again plaque accumulation, and therefore bacterial activity, will be minimized. If the inner surface is completely isolated and sealed from the oral environment there is a potential for remineralization under the restoration as well. The pulp can make a contribution towards remineralization, and it seems that glass-ionomer can add further mineral ions.

The external surface of the restoration is the most apparent and, of course, is the surface that can be kept under observation. It is exposed to the oral environment, and therefore has to withstand all the associated stresses. It should, if possible, be reasonably aesthetic, and it will be subject to all types of physical assault. The occlusal load can be very considerable, so that the compressive strength will need to be substantial. It will be subject in most mouths to rapid changes of temperature and heavy wear factors, and these forces can be exacerbated by the occlusion and by the presence of alcohols, aromatic oils and similar solvents.

It has been shown that glass-ionomer is relatively weak when first placed; but over a relatively short period of time it will mature, and its resistance to wear is such that, provided it is well supported by surrounding tooth structure, it will last many years. A probable explanation for this phenomenon is as follows.

It is known that the fluoride ions do not play an important role in the matrix of a glass-ionomer. This means that, in the presence of water, it is possible for them to migrate out of the cement into the surrounding saliva, from where they may be taken up into adjacent tooth structure and accumulated in the pellicle–plaque complex. On the other hand, if the ambient concentration of fluoride in the saliva, and therefore the pellicle-restoration interface, is high enough, it is possible for excess fluoride to return into the cement. It has been suggested therefore that glass-ionomer will act as a fluoride reservoir. It has also been shown that movement of fluoride ions out of the glass-ionomer will leave an electrolytic imbalance on the surface of the restoration. As this imbalance may not continue, cations from the plaque fluid and saliva may be taken back in to the surface of the restoration to reinstate equilibrium. This will return the material into a balanced state and at the same time lead to a degree of maturation and strengthening of the surface (Nicholson et al, 1999).

Evidence of this action has been demonstrated through immersion of 24 hours-old buttons of strontium containing glass ionomers in an artificial saliva solution. The solution was maintained at pH 4.5, to simulate an acid challenge in the oral environment. A known quantity of radioactive Ca^{45} was added to the solution. Subsequently it was found that there had been an active ion exchange, with strontium released from the specimen and Ca^{45} identified up to 200 microns down into the specimen (Figure 2.11).

It has also been shown that there will be a degree of fluoride uptake into the enamel surrounding a glass-ionomer restoration. While this has often been claimed as a preventive for recurrent caries, it is quite obvious at this time that no restorative material is capable of preventing caries. It is necessary actually to eliminate the infection that causes caries to bring the disease under control. However, the presence of additional fluoroapatite around the immediate periphery of a restoration will add to the resistance to further demineralization in that area, but will have no effect on the enamel beyond that.

A further advantage of the fluoride release lies in the fact that the *Streptococcus mutans*, the bacterial strain most closely allied to demineralization, fails to thrive in the presence of the fluoride ion. This means that plaque that accumulates on the surface of a glass-ionomer restoration will generally have a low *Strep. mutans* count. As a result, in spite of the difficulty of developing a really smooth

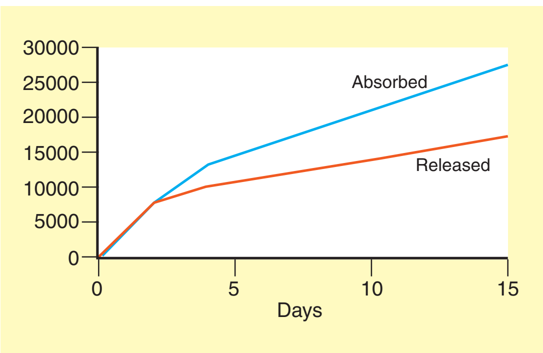


Figure 2.11

Radioactive Ca^{45} was found to penetrate into the Fuji IX pellet. As the amount of Ca^{45} that was lost from the solution was much greater than the amount extracted after 15 days it can be assumed that the final depth of penetration has not yet been determined.

gloss surface on these restorations, the tissue tolerance will remain very high, and there will be a significant lack of inflammation in surrounding gingival tissue (Figures 1.68 and 1.69).

Internal remineralization

The inner surface of a glass-ionomer restoration on the floor of the cavity is equally important because of the potential benefits that can arise from the ion exchange between underlying tooth structure and glass-ionomer. It cannot be observed and monitored clinically; but a number of controlled studies have noted a high level of remineralization when old glass-ionomers are removed for one reason or another.

As the dentine and the pulp should be regarded as one and the same structure it is worth noting recent observations on the interface between glass-ionomer and the vital pulp. It has been shown that the dental pulp demonstrates a very high level of tolerance to the presence of glass-ionomer. The poly(alkenoic) acids of the system are relatively mild acids with long and complex molecular chains, which will not readily penetrate dentine tubules, and the dentine itself is a very effective buffer to acids in general. Studies of the dental pulp have shown that there may be a very mild inflammatory response to the presence of freshly mixed glass-ionomer, followed by a rapid recovery over a period of a few days. Recent work has shown dentine bridging over a mechanical exposure, created in an otherwise healthy pulp, that was sealed with a glass-ionomer (Snuggs et al, 1993).

It has been accepted for some years that pulpal irritation is the direct result of bacterial activity (Brannstrom 1982), so that if there are no bacteria present there will be no inflammation. Lining materials are not expected to provide a therapeutic effect on the pulp; but if they provide a complete seal then bacterial activity cannot progress. This suggests that glass-ionomer, through its ion-exchange adhesion with tooth structure, will be an ideal sealant for a cavity, preventing the ingress of bacterial nutrients and reducing any that may be present to a dormant form. It is suggested, therefore, that glass-ionomer can be placed in very close proximity to the pulp without the risk of developing an irreversible pulpal inflammation, and the placement of a further sub-lining, such as calcium hydroxide, is not justified. Furthermore, softened, affected, demineralized dentine can be safely left under a glass-ionomer restoration, provided the margin is completely sealed around its full circumference.

The actual chemical reaction that takes place under a freshly placed glass-ionomer requires further investigation; but it is logical to assume that, immediately following placement, there is likely to be quite a ferment of chemical activity. The pH of the polyalkenoic acid itself is about pH1.9. On the assumption that the cement is placed on a newly conditioned dentine that is free of debris, the remaining mineral in adjacent dentine will be released by the polyalkenoic acid and will be free to mix with the ions released from the glass-ionomer. It can be assumed that there will then be a free exchange of ions in this isolated area until such time as the acid level is buffered by the phosphate ions. As the pH rises the cement will set and the ion exchange will slow down. It has been shown that the strontium ions can penetrate a considerable distance into dentine that had been partly demineralized by caries, leading to the development of what could be regarded as a type of dentine scar tissue.

There is considerable clinical and scientific evidence available at this point to support this theory; but the actual structure formed in the dentine scar tissue has yet to be determined in detail. However, as all other tissues in the body are capable of healing from trauma and developing some form of scar tissue there is every reason to believe that this is occurring in this situation. The illustrations from Figure 2.12 to Figure 2.17 show the accepted technique based upon the foregoing discussion for placement of a restoration in the presence of an extensive lesion.

Glass-ionomer as a bone substitute

Although the glass-ionomers were originally developed as a dental restorative material further work, originating from the late Robert Purrmann – one of the founders of ESPE Dental AG – has shown it to have considerable advantages as a bone cement and a bone replacement material. Many of the early clinical investigations were carried out by Professor LM Jonck et al. (1989a, b, 1990) at the University of Pretoria, Republic of South Africa,

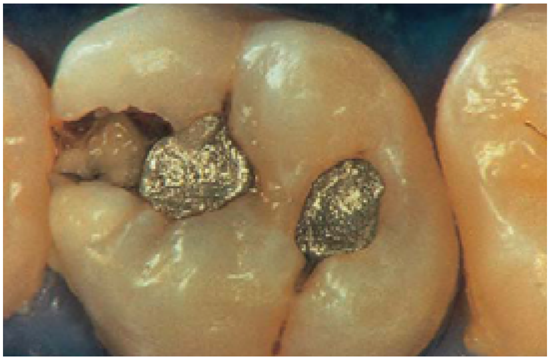


Figure 2.12

This patient presented with a difficult proximal lesion complicated by the presence of an old occlusal restoration that had been poorly placed and showed marginal leakage. The patient reported mild symptoms over a brief period.

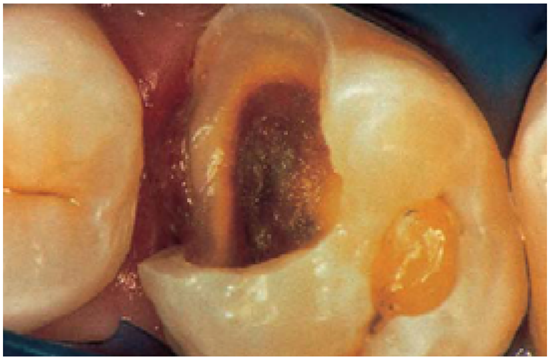


Figure 2.13

Most of the enamel from the buccal cusp was lost during cavity preparation, so the finished cavity design was very extensive. Note that the entire margin has been cleaned down to sound dentine, but the axial wall is still in softened demineralized affected dentine. This will be retained, because to remove it would almost certainly lead to a pulp exposure.

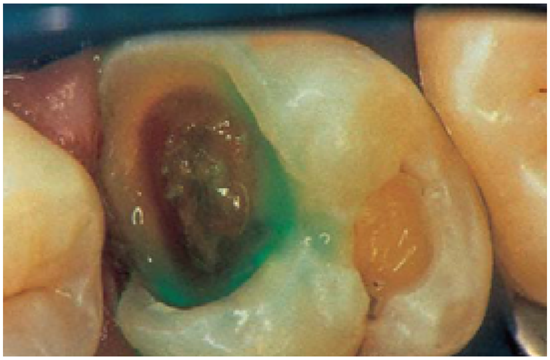


Figure 2.14

The completed cavity is now being conditioned with 10% polyacrylic acid for 10 seconds only. Note that the enamel transverse ridge has been retained, because to remove it would weaken the tooth crown, and an occlusal dovetail design is not required when using adhesive restorative materials.

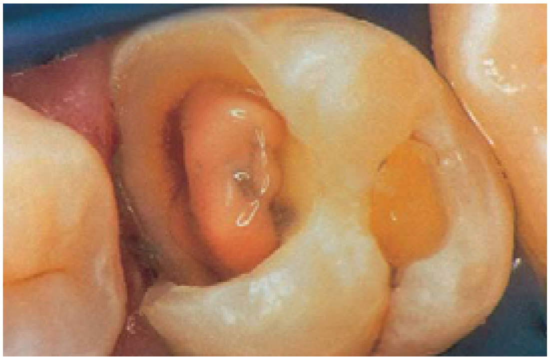


Figure 2.15

Following conditioning a small quantity of a light-initiated auto cure glass-ionomer is caused to flow over the axial wall and light-initiated to achieve a rapid set. The advantage of this 'sub-lining' is that it is relatively strongly antibacterial, and this is desirable in this position.

Figure 2.16

A high-strength auto cure glass-ionomer is now laid down over the sub-lining and allowed to cure. It is then cut back to expose the enamel walls, so that the remainder of the cavity can be restored with composite resin. Another advantage of the light-initiated glass-ionomer is that it is easily detected below the overlay of stronger glass-ionomer while trimming the base ready for the laminate. The entire cavity is now being covered with a thin layer of a resin modified adhesive glass-ionomer.

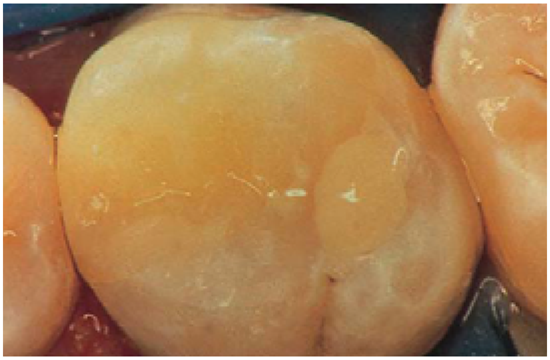


Figure 2.17

The completed restoration, following an incremental build-up with composite resin. Note that the distal fissure will remain restored with a high-strength auto cure glass-ionomer only.

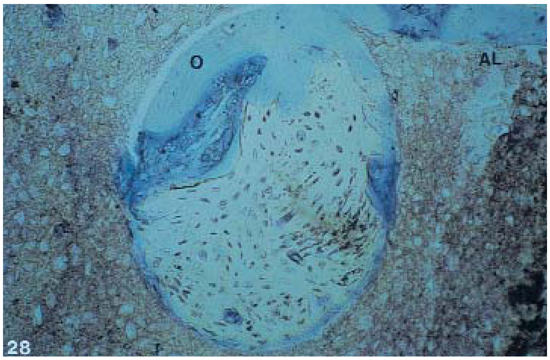


Figure 2.18

A freshly mixed glass-ionomer cement was placed in vivo and subsequently harvested. This large porosity shows osteoid tissue growing within, suggesting that there is a high degree of biocompatibility between the cement and the surrounding tissue. (Illustration courtesy of ESPE GmbH.)

and work continues, mainly in the United States of America. Some of this work duplicates the work discussed above, and reinforces the concept that glass-ionomer is both highly bioactive and biocompatible.

The major landmarks in the development of these materials include the formulation of defined-composition ionomer glasses as well as an improved understanding of their biological and material properties in general (Brook & Hatton 1998). It has now been shown that they can form a stable integration with bone and can affect both its growth and development adjacent to the surface of the material through an ion-release mechanism similar to that which is apparent in dentistry. Successful clinical use both as cements and as preformed bone replacement parts has been demonstrated in otological surgery as well as in oral and reconstructive surgery (Figure 2.18). However, it must be noted that contact

between unset glass-ionomer and neural tissues is strictly contraindicated.

It is interesting to note the parallels between this application and the studies discussed above, which reveal the ion exchange in the oral environment.

Glass-ionomer as a bone cement

One of the great challenges facing materials science today is the development of a new generation of biomaterials to repair the human body. The population is aging, and large numbers of people receive implants annually to help maintain their quality of life. An important use of implants is to repair, replace or augment diseased or damaged parts of the skeletal system. For many years the guiding principle used in biomaterials development was that the materials should be as chemically inert as possible. Body fluids are highly corrosive saline solutions, and the materials had to be strong enough to withstand the environment.

The first materials used in skeletal repair were metals optimized for strength and corrosion resistance. Metallic implants for orthopaedic and dental applications have been very successful, with hundreds of thousands being implanted annually. The original applications were as removable devices, such as those for stabilization of fractures. Use as permanent joint replacements began in the 1960s with Professor Charnley's use of self-curing polymethymethacrylate (PMMA) 'bone cement', which provided a stable mechanical anchor for a metallic prosthesis in its bony bed. This type of anchoring of implants to bone is called 'morphological fixation' or 'cement fixation' if PMMA cement is used. High levels of clinical success, averaging 85% over 10 years, of 'cemented' metallic orthopaedic implants have led to rapid growth in their use, especially for hip and knee replacements.

However, the use of PMMA bone cement may result in death of the bone at the interface, owing to an exothermic reaction during polymerization. The dead bone is less elastic and weaker than living bone and is easier to fracture. Cellular remodelling of the dead bone also occurs, which leads to additional weakening of the implant–cement interface. There is an additional biomechanical problem; the elastic modulus of the implant and PMMA cement is much higher than that of the surrounding living tissue. This mismatch across an interface means that the higher-modulus implant will carry most of the load. Thus, the bone will be 'stress shielded'. This is undesirable, because living bone must be under some tensile load to remain healthy. Bone that is unloaded or is loaded in compression will undergo a biological change that leads to resorption and weakening.

As a result of the foregoing problems the glass-ionomers are now being used instead of the PMMAs. One of the major advantages with these materials is that the setting reaction will produce no exotherm, so that there will be no damage to surrounding tissue at the implant site, nor will it affect heat-labile drugs that may be in use. The unset material will chemically bond to both bone and some metals and, during setting, will not undergo any significant shrinkage. While the physical properties are inferior to those of the acrylic cements, work continues on improving them, and, in the meantime, it is suggested that they are ideal for any situation that is not under undue load (Figure 2.19).

Immunohistochemical studies of implanted glass-ionomers have shown close association of the non-collagenous extracellular matrix proteins of bone (osteopontin, fibronectin, and tenascin) with the surface of the cement. These factors, which are known to play an important role in osteogenesis and the osteointegration of biomaterials, together with the hydrophilic surface of the glass-ionomer, may explain the osteoconductive properties of this material when implanted. Radiographic microanalytical studies of set glass-ionomer have shown that ions released from the glass particles during the gelation process are present in the matrix as well as in the adjacent bone. Even after full gelation has occurred there is mobility of ions within the cement, as well as an exchange of ions with the aqueous environment. Actual ion release is determined by the composition of the glass as well as the biochemical environment of the implant bed.

Early investigations emphasized the fluoride release, and it was noted that non-fluoride glasses were the least toxic in vitro but the least osteoconductive in vivo. At high concentrations in vitro the glass appears to act as an enzyme inhibitor, but in vivo it stimulates proliferation of bone-forming

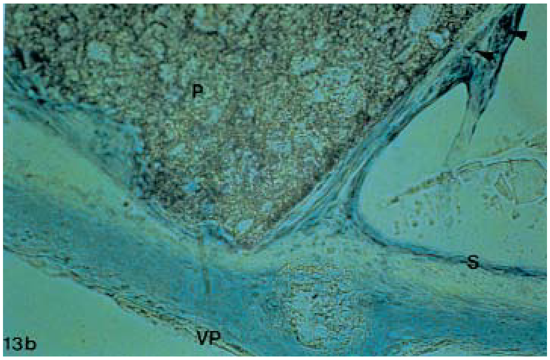


Figure 2.19

A section through a piece of a preformed glass-ionomer implant incorporated as part of the reconstruction of an ear and subsequently harvested. By contrast with the situation in the preceding illustration, here the glass-ionomer was already fully set before placement. Note the close adaptation of the soft tissue to the implant, confirming the biocompatibility of the set cement. (Illustration courtesy of ESPE GmbH.)

cells and increases bone density. It is expected that there will be formation of fluoroapatite and, as this is more resistant to bone resorption, it is particularly useful in the presence of osteoporosis. It has also been noted that there is a release of other ions as well, and both calcium and phosphate ions have been related to the inherent bioactivity. However, it is the aluminium ion release that is most controversial, and this has been related to adverse reactions from direct contact with neural tissues.

The use of pre-formed glass-ionomer items has made the greatest impact on otological surgery, where they are used both as prosthetic implants of ear ossicles and as granular bone substitutes. For incus replacement a prosthesis measuring 5 mm in length is marketed and, for replacement of both incus and stapes superstructure, machine-tooled 8 mm prostheses are available. These can be modified for the particular circumstances using a fine diamond bur. The replacement material is then covered with a vascularized pedicled flap of canal wall skin or an anteriorly based pedicled periosteal flap. Geyer and Helms (1990, 1993) reported a high success rate for reconstructive middle ear surgery that included reconstruction of the auditory canal, reduction of the mastoid cavity and rebuilding of the ossicular chain. Glass-ionomer has also been used for cementation of cochlear implants. In oral surgery it has been successfully applied to prevention of bone loss following extraction, as well as a filler for bone donor sites and cyst cavities.

3 Type I: Luting and bonding

Description

Following the introduction of alumino-silicate-(poly)acrylic acid (ASPA), the next of the glass-ionomers to be developed and marketed was designed for luting crowns and bridges, and it has proved to be highly successful. It has now been in use for about 25 years and it has largely replaced all other types of acid–base cements for this particular task. There were some early problems, related mainly to clinical handling, but these seem to have been overcome, and probably its nearest rival now is the resin-type luting agents that have recently become popular.

A further variation of the low powder content, low viscosity glass-ionomers is currently being marketed as a bonding agent for composite resin and amalgam. There has been some recognition of the problems associated with the use of resin bonding agents related to their inability to develop long-term adhesion between composite resin and dentine, and the glass-ionomer alternative is becoming popular.

As the luting cements and the bonding glass-ionomers are very similar in both chemistry and clinical application they will be dealt with together in this chapter.

Luting cements

The chemistry of the luting materials is essentially the same as that of the rest of the glass-ionomer family and Chapter 1 will explain the basic essential elements and properties (Figure 3.1). However, the size of the powder particles is finer, in the range of 4–15 µ, to ensure achievement of an ultimate film thickness of between 10 and 20 µ. Flow properties are such that placement of a restoration into a cavity to its full extent is relatively easy. Unlike the zinc phosphate cements, glass-ionomer luting cement does not have an elastic memory, so it is not necessary to maintain positive pressure on the restoration during the initial setting period (Figures 3.2, 3.3) (White et al, 1992).

When using the old-style zinc phosphate cements for luting, it was possible to vary the setting time to some degree. Chilling the slab to just above the dew point and adding the powder in small increments gave the clinician some degree of control over working and setting times. However, this theoretical advantage was offset to some extent by the fact that the viscosity was higher and the flow properties lower than those of the glass-ionomers, and also phosphate cements had an 'elastic memory'. This meant that it was necessary to maintain positive pressure after completing placement to ensure that the appliance did not lift off the tooth before the cement was set. The best way of overcoming the problem was to vent the crown prior to placement, thus allowing the escape of excess cement from the occlusal surface of a well-fitting appliance.

With the glass-ionomers the viscosity of the newly mixed material is low, and the appliance will slide easily into position, leaving a very fine film thickness. There will then be a rapid 'snap' set, whether the slab is chilled or not and regardless of the rate at which the powder is incorporated into the liquid. Increase in viscosity and achievement of a snap set varies between products. The anhydrous types of glass-ionomer, wherein the polyacrylic acid is dehydrated and incorporated in with the powder, tend to allow a longer working time before becoming too

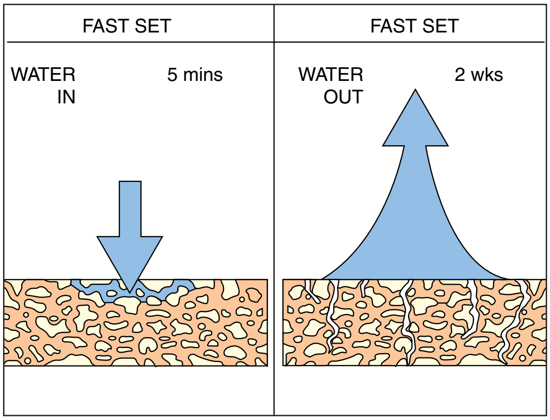


Figure 3.1

Diagram showing the water balance of the Type I glass-ionomer materials. Note that they are resistant to water uptake within about 5 minutes of the start of mix, but remain subject to water loss for about 2 weeks after placement.

Figure 3.2

A porcelain-bonded-to-metal crown that was removed about 2 years after placement because of loss of porcelain. It has been cut in two to show the glass-ionomer still attached to the gold rather than to the tooth. Note also the even layer of cement over the entire surface, although the crown was not vented.

Figure 3.3

A crowned tooth was lost approximately 10 years after placement for periodontal reasons. It had been luted with a glass-ionomer, so it was sectioned to assess the accuracy of cementation. It was not vented, but the fitting surface of the crown had been lightly etched to allow room for the cement. Note the fine fit at the margin, suggesting that the glass-ionomer had flowed well during placement.

viscous to permit full placement of the restoration (Figures 3.4, 3.5).

With the finer particle size, working and setting times may be reduced, and physical properties are improved. At the required low powder–liquid ratio the compressive and shear strength figures are relatively low; but this is really not important, because no luting cement is expected to be the principal method of retaining the restoration in place. The design of the cavity or preparation is all-important for retention, and the lute is there simply to seal the space between restoration and tooth (McComb 1982). Solubility is a far more important property, and, in this regard, the glass-ionomers are significantly less soluble than the zinc polycarboxylates and a little better than the zinc phosphates.

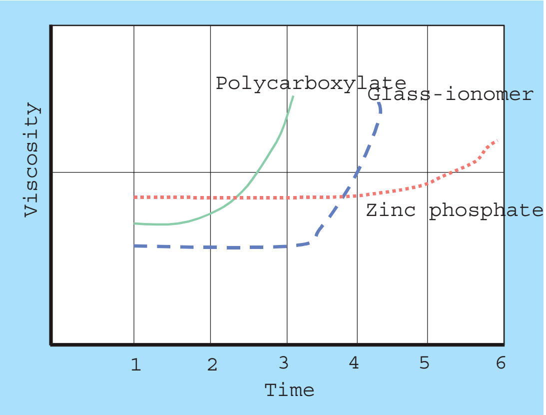


Figure 3.4

Comparison of development of viscosity of freshly mixed cements and ability to allow complete seating. Note that zinc phosphate cement is initially more viscous, but allows seating for longer than the glass-ionomers. (Adapted from Oilo & Evje 1986.)

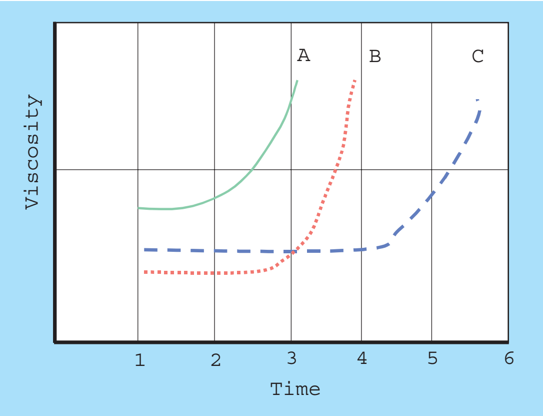


Figure 3.5

Rapid development of viscosity in glass-ionomers. All glass-ionomers tend to a 'snap' set once the viscosity begins to rise, so the available working time is not long. (Adapted from Oilo & Evje 1986.)

A, A luting cement containing dehydrated poly(acrylic acid) in the powder and using water as the liquid;
B, A luting cement that uses poly(acrylic acid) as the liquid;
C, A luting cement containing dehydrated poly(maleic acid) in the powder with dilute tartaric acid as the liquid.

Reasons for use

The zinc phosphate cements have now been in general use for the best part of a century for the cementation of crowns and bridges, and it is reasonable to question the need to replace them. They are apparently safe to use, relatively insoluble and last many years. The zinc polycarboxylate cements were developed by Smith in the middle 1960s, and offered the possibility of adhesion to both tooth structure and the noble metals. However, the tensile strength was quite low, and therefore the promised adhesion to tooth structure was relatively short-lived, and their popularity waned rather rapidly. In recent years there have been a number of resin luting cements developed, particularly for use in the cementation of highly translucent crowns and labial veneer restorations. Subsequently their use has spread beyond this limited field, and they are being used more widely in advanced crown and bridge prostheses. They have high physical properties, but it is difficult to achieve a low ultimate film thickness, and this means that they need to be handled with considerable care to ensure full placement and acceptable ultimate film thickness.

The glass-ionomers show adhesion to tooth structure similar to the polycarboxylates, and their tensile strength is at least as high as that of the zinc phosphate cements. They should not be used to try to retain a casting that does not demonstrate a good firm fit in the first place because shortcomings in design cannot be compensated by an 'adhesive' cement (Dahl et al, 1986). In this area there may be some value in using a resin lute because the physical properties are such that, once having placed a restoration, it is almost impossible to remove it – and this, of

course, can be both an advantage and a disadvantage. The question then is why select a glass-ionomer instead of a zinc phosphate or a resin lute (Metz & Brackett 1994).

The following factors are in favour of a glass-ionomer lute:

- The tensile strength of the glass-ionomer is at least as high as that of zinc phosphate.
- The solubility of glass-ionomer is lower.
- The thixotropic flow properties of the glass-ionomer allow for easier placement of the prosthesis without the need to vent the casting or to retain pressure during setting.
- It is easier, therefore, to achieve an acceptable ultimate film thickness.
- The potential for post-insertion sensitivity is the same for all cements and is dictated by factors other than the cement.
- There is the potential for an ongoing fluoride release with the glass-ionomers.

When comparing glass-ionomer and zinc phosphate cements with resin cements, the following factors should be taken into account:

- With the resin cements micromechanical adhesion with underlying tooth structure may be available following etching of the dentine.
- The tensile strength of the resin cements is greater than that of the other two.
- The effect of long-term hydrolytic breakdown with the resin cements is not yet fully explored.
- Pulp compatibility of the resin cements is not yet fully explored.
- Ultimate film thickness with the resin cements is relatively high.
- There is no fluoride release with the resin cements.
- The resin cements are essentially insoluble.
- There may be problems in case of failure of one section of an appliance, because it may not be possible to remove the appliance without destroying it.

Significant factors

Powder–liquid ratio

Powder–liquid ratio is generally about 1.5:1, and will be specified by the manufacturer. A moderate increase in powder content is acceptable, although this may reduce the working time and, if increased too far, may lead to an unacceptable ultimate film thickness. Reduction of the powder content by 10% will reduce ultimate physical properties to a significant degree, and may prolong the setting time and increase solubility. The pH of the newly mixed cement is normally quite low – approximately pH 1.8 – but, under normal circumstances, it will rise to pH 4.5 within the first 30 minutes. In the presence of a reduced powder content the pH will remain low for a prolonged period, and may lead to post-insertion sensitivity (Figures 3.6, 3.7).

Dispensing in capsules and machine-mixing is the best method of handling, and will ensure standard repeatable results. If mixing is to be carried out by hand, the working time can be extended to a limited degree by chilling the slab and the powder – but not the liquid – to a temperature just above the dew point.

Dispensing and mixing

Hand mixing is always possible with all the glass-ionomer materials; but the problem is always that of accurate measurement of the proportions. The manufacturers supply the liquid in a dropper bottle, and most of these will dispense a reasonably standard drop. The main problem comes with the powder, and accuracy is difficult to maintain, particularly in the middle of a busy day. A 10% variation either way with the powder will be sufficient to alter either the flow or the ultimate strength of the mixed material, and the result can be the failure of a very expensive prosthesis.

It is strongly recommended that capsulated materials be used, for two reasons. First, the standard of accuracy of dispensing is very high indeed; and secondly, the capsule becomes a syringe, and this is the most convenient means for placement on to the tooth and into the prosthesis.

A recent innovation is the introduction of a luting cement that is dispensed as two pastes rather than a powder and a liquid; and this facilitates hand mixing on a slab. It is marketed in a double syringe, so there is no doubt about the proportions of the two elements. One syringe contains the glass powder, which is converted to a paste using a monomer as well as 20% by weight

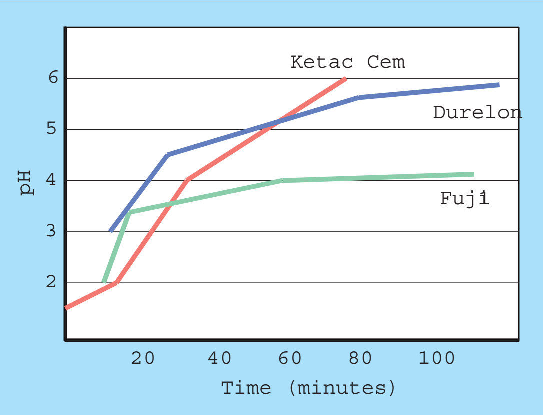


Figure 3.6

The initial pH of luting cements is rather low at the time of mix. However, the pH of all three types rises quite rapidly following insertion of the prosthesis. (Adapted from Charlton et al, 1991.)

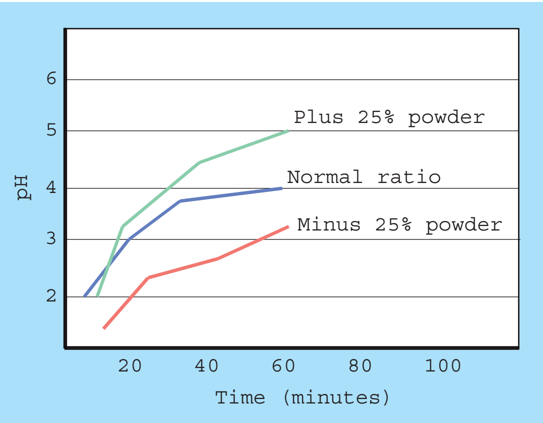


Figure 3.7

The powder–liquid ratio has a bearing on the speed at which the pH rises. A 25% reduction in powder content leaves the pH low for longer, thus increasing the risk of post-insertion sensitivity. (Adapted from Charlton et al, 1991.)

of HEMA. The second half of the double syringe contains the polyacrylic acid, as well as the required water, thickened to the correct consistency with very fine silica. Both syringe barrels contain traces of the required catalysts and, following mixing, the ultimate HEMA content will be less than 10% by weight. This means that it is in fact a resin-modified material; but it is fully auto cure, and does not need to be exposed to the activating light.

The two nozzles are graded in size, so that extrusion of identical lengths will ensure correct proportions. Mixing is simplified; but it must be stressed that the two components need to be fully and carefully mixed. Other, similar types of impression materials are colour-coded, so that they can be mixed to an even colour, but the two pastes in this case are of a similar colour, so that the same principle cannot be applied. Therefore take care to mix vigorously for at least 10 to 15 seconds, as recommended by the manufacturer, to make sure the two components are fully integrated.

One of the advantages of this method of dispensing is that it is possible to vary the size of the mix to suit the complexity of the prosthesis. Also, the ultimate film thickness is claimed to be in the range of 4–10 μ, and setting time is generally within normal clinical limits.

Time to mature

Under many circumstances, the gingival margin of a restoration will be subgingival, and therefore it

will be impossible to isolate the cement entirely from salivary contamination during cementation. It is therefore desirable for luting cements to be fast-setting and to have high resistance to water contamination within 5 minutes of the start of mix. It is then unnecessary to attempt to seal the cement under a waterproof varnish or resin bond. It should be noted, however, that the glass-ionomers remain subject to dehydration if left isolated for longer than 10 minutes from the start of mix. This means that the water balance must be maintained by removing the excess and releasing the cement to the oral environment as soon as it is set. Periodically test the stage of set by probing with a blunt instrument until it is crisp and firm and will break away freely.

Adhesion to enamel and dentine

It is possible to develop the standard ion-exchange adhesion to both dentine and enamel; but it is suggested that it may be unwise to pursue this too vigorously. As was discussed above (see page 28), it is necessary to remove the smear layer to develop optimum ion-exchange adhesion, and this, in turn, may well expose the dentine tubules and remove any dentine plugs that are obliterating the lumen. There will be considerable hydraulic pressure developed during cementation of a full crown, and this may allow penetration of polyacrylic acid into the tubules, leading to undue irritation of the pulp tissue and post-insertion sensitivity. This means that it is generally desirable to seal the surface of the dentine rather than removing the smear layer. There are a number of ways of achieving this, including application of a mineralizing solution at the time of preparation and just prior to construction of the temporary appliance.

It must be noted that it is possible to gain a degree of adhesion to noble metals by electroplating the fitting surface of the restoration with a 2–5 μ layer of tin oxide immediately prior to placement (Wilson & McLean 1988). Of course, for restorations constructed by an indirect technique, retention should be derived from the design of the preparation and the fine fit of the restoration. The luting cement should be present only to seal the interface between restoration and tooth, and should not be relied upon to provide adhesion.

Cementation on vital teeth

In cementation of a full crown it is possible to develop considerable hydraulic pressure, so it is undesirable to open up dentinal tubules to any degree at all (Figures 3.8 to 3.16). Therefore conditioning the surface of the dentine and removing the smear layer with mild acids, such as 10% poly(acrylic acid), is contraindicated. If the dentine is to be sealed, apply a mineralizing solution such as 25% tannic acid for approximately 2 minutes. An alternative is to apply a dentine-bonding agent that contains a poly(alkenoic acid), in particular maleic acid, because this will form a hybrid layer on the dentine surface similar to the ion-exchange layer developed by a glass-ionomer. The best time to apply the seal is after making temporary restorations and taking the final impressions, and immediately before cementation of the temporaries. The surface of the dentine will then be sealed during the temporary phase, with a reduction of sensitivity both at the time of cementation and subsequently.

Cementation on non-vital teeth

If the restoration is being placed on a non-vital tooth, development of the optimum ion-exchange adhesion is desirable (Figures 3.17 to 3.25). The remaining tooth structure should be conditioned with an application of 10% poly(acrylic acid) for 10–15 seconds to remove the smear layer, washed thoroughly and then dried lightly. Do not dehydrate unduly, and then apply the cement without further contamination. This routine applies particularly for cementation of a cast post into a root canal, because the very best adhesion possible is desirable at this time.

Fluoride release

Fluoride release is available, but, in the light of the small quantity of cement present at the margin, it cannot be relied upon for remineralization of adjacent and surrounding tooth structure. It can be argued that it will discourage plaque formation, and it will certainly do no harm. However, control of the disease is the

Cementation on vital teeth

Figure 3.8

Cementation of crowns on three upper anterior teeth. The temporary crowns have been removed and the remaining temporary cement has been gently taken off without scrubbing.

Figure 3.9

The teeth are washed only and not conditioned with poly(acrylic) acid, so that the smear layer is retained. The surface can be sealed with a mineralizing solution if there is a risk of post-insertion sensitivity.

Figure 3.10

If the cement is to be handmixed dispense at the correct powder–liquid ratio and mix to the correct consistency within 25 seconds. Do not over-spatulate. The cement should string up 2–3 cm from the slab before breaking and slumping back.

Figure 3.11

Apply cement to the inside of the crown with a fine bristle brush, making sure to paint the margins in particular.

Figure 3.12

Paint a small quantity of the cement on to the tooth.

Figure 3.13

Seat the crowns and apply firm positive pressure with an orangewood stick. Once the crowns are seated fully, there is no need to maintain pressure.

Figure 3.14

Wait until the cement is set to the stage where it cannot be indented with a sharp instrument, and immediately remove the excess from the margins. Do not delay, because the cement will continue to harden and become more difficult to remove.

Figure 3.15

Carefully remove all debris from within the gingival crevice.

Figure 3.16

The cemented crowns 1 week after insertion.

Cementation on non-vital teeth

Figure 3.17

Cementation of a post and crown on an upper-right lateral incisor. The temporary crown and post have been removed and the preparation cleaned.

Figure 3.18

The root face and posthole are conditioned with 10% poly(acrylic acid) for 10–15 seconds to remove the smear layer and enhance retention.

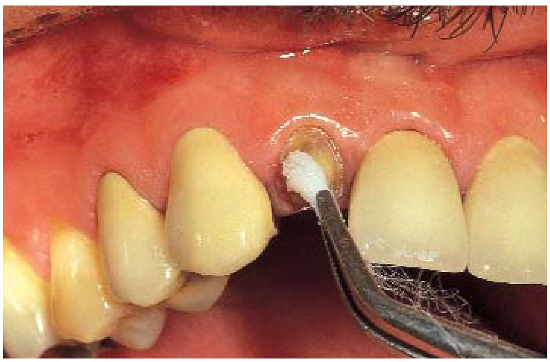


Figure 3.19

The area is washed thoroughly and dried with alcohol, paying particular attention to the apical end of the posthole.

Figure 3.20

Cement is mixed as required, and a little is painted on to the post.

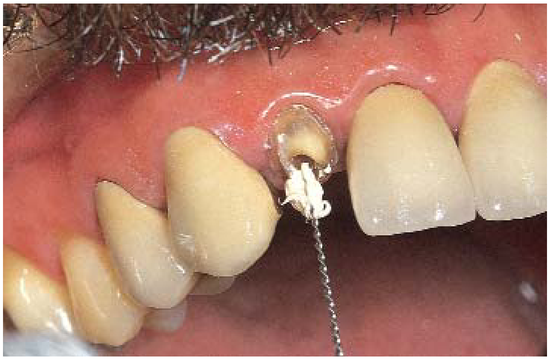


Figure 3.21

Cement is wound into the posthole using an engine-driven Lentulo spiral or similar. The canal is filled to the top.

Figure 3.22

The post is positioned and adequate pressure is applied to seat it using a wooden spatula. There is no need to maintain pressure.

Figure 3.23

The inside of the crown is painted with cement using a small, stiff-bristle brush.

Figure 3.24

The crown is positioned and pressure is applied with a wooden spatula. There is no need to maintain pressure.

Figure 3.25

The finished crown about 6 months after cementation.

most important factor in prevention of further caries.

Pulp compatibility

There has been some controversy concerning possible adverse pulp response and post-insertion sensitivity when using some of the materials in this group. However, there is a high degree of compatibility between the cement and the pulp under normal circumstances (Cox & Suzuki 1994), and the dentine is, in itself, a very efficient buffer against variations in pH levels (Heys et al, 1987). Clinical surveys have suggested that the incidence of sensitivity is not, in fact, at variance with that for other cements, such as the zinc phosphate group (Brackett & Metz 1992). Certainly there can be generation of considerable hydraulic pressure, particularly when placing a full crown, and this may complicate the response if the dentinal tubules have been opened up by removal of the smear layer. It is suggested therefore that a vital tooth should not be conditioned prior to cementation. The alternative is to seal the surface with a mineralizing solution or 25% tannic acid for 2 minutes at the time of preparation. Venting of full crowns is a further precaution that may assist in avoiding problems by reducing hydraulic pressure.

Physical properties

The physical properties have been shown to be equivalent to, or better than, those of the zinc phosphate cements, and the glass-ionomers are becoming the standard against which other luting materials are measured. Solubility is low, provided that the powder–liquid ratio is that recommended by the manufacturer, and compressive and tensile strength is adequate, because of the fine particle size. Radiopacity is desirable, so that cement residue can be detected in areas of difficult access.

Bonding with glass-ionomers

Bonding composite resin

For a number of years there has been a concentrated search for an effective bonding agent to ensure adhesion between dentine and composite resin (McLean 1996). Buonocore showed nearly 50 years ago how to develop a micromechanical adhesion with enamel. However, there are many differences between enamel and dentine, and the problems of developing adhesion between dentine and a bland, biologically inactive material such as composite resin are manifold. Research to date has concentrated on some combination of resins, but so far there has been no comprehensive success. There is a trend at this time to the use of a glass-ionomer as a bonding agent, and there are encouraging signs of success (Yamada et al, 1996).

Wilson and McLean (1988) showed how to develop a laminated restoration as a two-stage procedure, and this has been successfully used ever since. The lamination technique is discussed in detail in Chapter 6. However, there are occasions when the cavity is so shallow that there is not sufficient room to place both a glass-ionomer and a composite resin, and an alternate technique may be useful.

The concept is that there should be a low-viscosity, low powder–liquid ratio, resin-modified glass-ionomer placed first on the floor and walls of the cavity and light-activated (Burrow & Tyas 1998) (Figures 3.26 to 3.33). The composite resin can then be placed over this and built incrementally as required. The composite resin, of course, will set immediately and undergo its full degree of shrinkage. The polymer section of the glass-ionomer will also set and shrink; but the acid–base setting reaction will continue for some time, as discussed in Chapter 1, and will be able to compensate, to at least a degree, for the shrinkage of the composite resin. There will certainly be less stress at the union, and clinical results suggest that the concept is worth pursuing. Some authors suggest that this type of bond will be sustained over time, whereas resin–dentine bonds tend to reduce in strength as they hydrolyse.

A number of materials in this category are available and have shown acceptable clinical results. The powder is a standard fluoroaluminosilicate glass, and the liquid contains a relatively high proportion of HEMA and dimethacrylate, as well as a photoinitiator. A special conditioner is supplied with some of the materials, and this contains aluminium chloride as well as polyacrylic acid. The expectation with this is that the smear layer will be removed and a fine layer of crystals will be laid down on the dentine surface to seal it.

The clinical routine should be as follows:

- prepare the cavity as normal.
- condition the cavity with the conditioner supplied for 10 seconds only, wash and dry lightly – do not dehydrate.
- mix the proprietary glass-ionomer bonding agent as directed.
- paint a thin layer over the entire cavity surface including the walls.
- blow off excess with compressed air, and take care that it does not puddle in the corners.
- light-activate the bonding agent for 20 seconds.
- place the composite resin incrementally as indicated and model to shape.
- light-activate the restoration from several angles as required, to minimize problems from shrinkage.
- finish contouring and polishing and adjust the occlusion.

Note that this system will work best with relatively small shallow cavities that can be reliably restored with a single increment of composite resin (Burrow & Tyas 1998, 1999). In extensive cavities, particularly proximal lesions where the cavity extends beyond the enamel at the gingival floor, it is suggested that it would be better to use the full lamination technique as discussed in Chapter 6.

Bonding amalgam

Amalgam is a completely inert material that shows no interaction with the host tooth structure, and therefore requires some degree of mechanical interlocking device within the cavity to prevent it falling out. In addition, as the cavity becomes larger the remaining tooth structure becomes weaker, and it would be highly desirable if the two could be bonded together.

Figure 3.26

An extensive occlusal cavity in a technique case that will be restored using a glass-ionomer bond with a composite resin placed over it. It will then be sectioned and examined under the SEM.

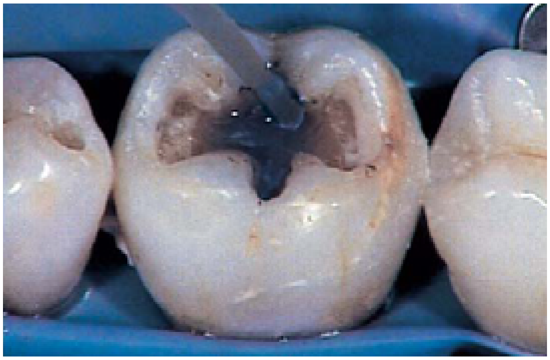


Figure 3.27

The cavity is conditioned for 10 seconds prior to placement of the glass-ionomer bond to remove the smear layer and prepare the tooth surface for a glass-ionomer bond.

Figure 3.28

The glass-ionomer bond is mixed according to manufacturers' instructions and a thin layer is painted over the cavity surface. Excess will be blown off and the bond light-activated for 20 seconds before the composite resin is built up incrementally.

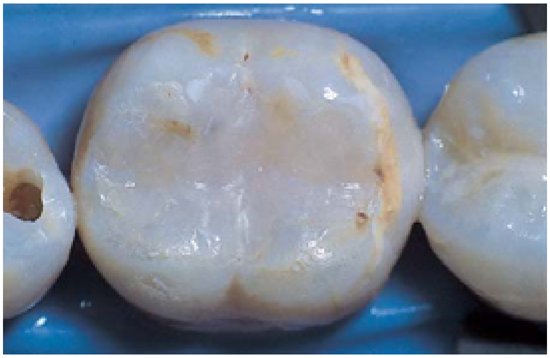


Figure 3.29

The completed restoration. This will now be sectioned bucco-lingually across the midline to examine the union between the restoration and the tooth.

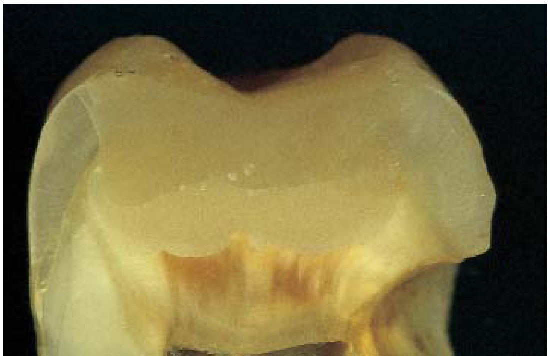


Figure 3.30

One half of the tooth and restoration, which has been polished under water to 1000 grit on wet and dry paper, and then lightly etched with orthophosphoric acid to remove the surface smear layer.

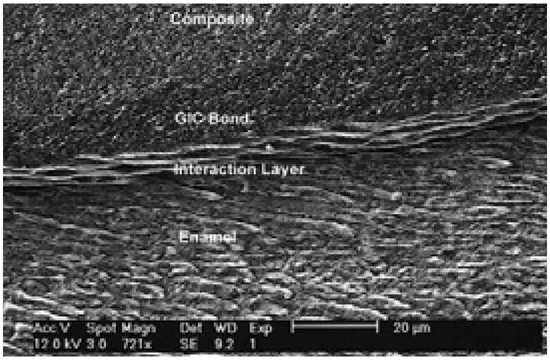


Figure 3.31

A scanning electron micrograph of another specimen showing the various materials involved in the adhesion. The ‘interaction layer’ is better known as the ‘ion-exchange layer’. Magnification × 721.

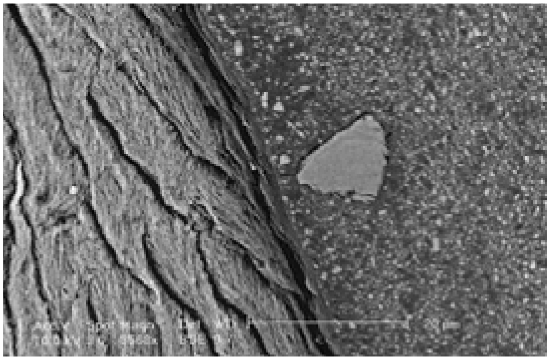


Figure 3.32

The union between the enamel and the composite resin part way up the margin on the left-hand side. Note the orientation of the enamel rods, suggesting that there is not likely to be a good micromechanical adhesion with composite resin only and that the presence of the glass-ionomer bond will enhance the union. Magnification ×3500.

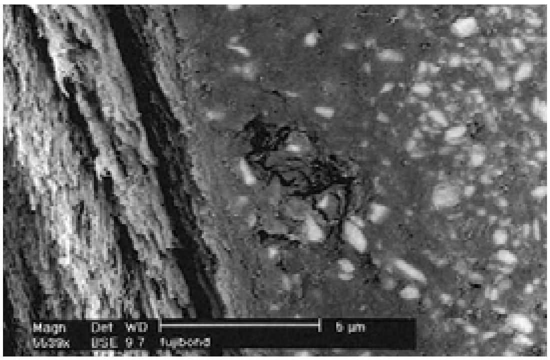


Figure 3.33

A higher magnification of a similar area of the bond. Note the small defect in the glass-ionomer bond, which is common along the entire union. The apparent gap between the glass-ionomer and the enamel is an artefact. Magnification ×5600.

The only possible alternatives in past years have been either mechanical interlocks using ditches and grooves within remaining tooth structure or pins threaded into the dentine to enhance retention. Dovetail interlocks are, in fact, very effective when developed in the gingival one-third of the crown, and have a proven record of success. However, this does not solve the problem of the maintenance of fragile remaining cusp fragments that may be of some aesthetic value to the ultimate restoration.

Threaded pins have been used extensively since the middle 1950s, and have been through several editions. The main problems are that, over time, they weaken both the tooth and the amalgam, and after about 15 years on average they are likely to fail. There are other hazards in their placement, including the possibility of penetrating either the pulp or the periodontal ligament, thus adding further complications to an already difficult situation.

For some years now the resin–dentine bonding systems have been used in an attempt to develop long-term adhesion between tooth structure and amalgam (Figures 3.34 to 3.39). Short-term results appear to support the concept; but it would seem that the resins hydrolyse over time, and success is short-lived (Smales & Wetherell, 2000; Mahler & Engle 2000). Recently there have been a number of investigators testing the validity of using the glass-ionomer bonding agent that has been discussed above in relation to composite resin (Gordan et al, 1999; Al-Moayad et al, 1993). Long-term results are not yet available, but the concept is reasonable. Some short-term reports, however, suggest a reduction in post-insertion sensitivity to temperature change in a newly placed amalgam restoration (Gordan et al, 1999).

The clinical routine should be similar to that discussed above:

- condition the cavity with the prescribed conditioning agent for 10 seconds, wash and dry lightly – do not dehydrate.
- mix the glass-ionomer bond according to manufacturers' directions.
- paint a thin layer over the entire cavity and blow off excess.

Figure 3.34

A similar technique case that will be restored with a glass-ionomer bond and amalgam.

Figure 3.35

The cavity has been based with a glass-ionomer because of the depth and the presence of some demineralized dentine on the floor. This remains on the assumption that it will remineralize in the presence of the glass-ionomer. The cavity is now being painted with a small quantity of a glass-ionomer bond.

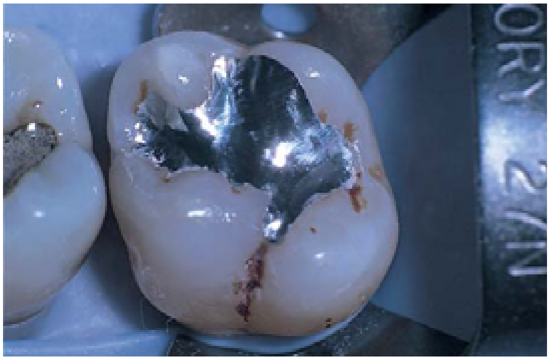


Figure 3.36

The excess bond has been blown off and the remainder light-activated. The amalgam has been condensed in the usual manner and finally polished.

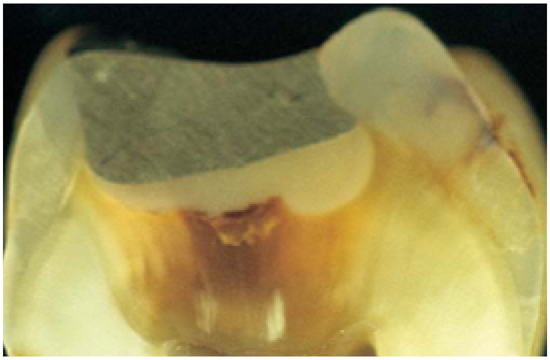


Figure 3.37

The tooth was then sectioned bucco-lingually so that the bond could be examined.

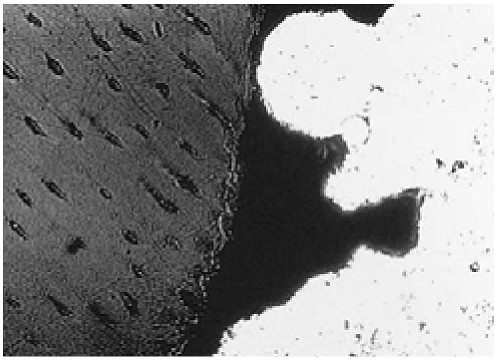


Figure 3.38

A scanning electron micrograph of the margin between the amalgam and the tooth surface along the buccal wall. Note the irregularity in the amalgam, suggesting that the glass-ionomer bond material has been disturbed during condensation.

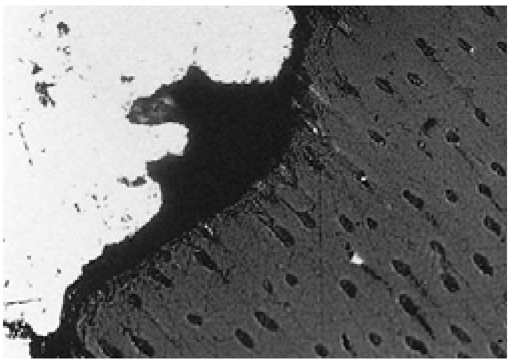


Figure 3.39

A scanning electron micrograph of the corner at the floor on the right side of Figure 3.37, which again suggests that the glass-ionomer bond was disturbed during condensation.

- light-activate the bond for 20 seconds at least.
- immediately pack the amalgam as usual in small increments using heavy condensation.
- complete the placement of the amalgam as usual, including burnishing the margin towards the cavity walls.

It would seem that the greatest hazard with this technique would be the potential for incorporating fragments of glass-ionomer bond into the amalgam during vigorous condensation, thus downgrading the physical properties of that material. There will certainly be an ion-exchange adhesion developed between the glass-ionomer and the tooth structure, and potentially a mechanical interlock between the amalgam and the bond. Whether this is sufficient to ensure long-term union has yet to be proved. There will also be a small fluoride release that may be of some value, although the only effective method of preventing recurrent caries is by eliminating the disease. The bond will not have high physical properties because of the low powder–liquid ratio used when mixing the material, so expectations should not be too high. Unless remaining thin sections of weakened cusps are protected from occlusal load by the cavity design this bonding technique is unlikely to be sufficient to prevent cusp loss (Mount and Ngo 2000).

4 Type II.1: Restorative aesthetic materials

Description

The original glass-ionomer released to the profession in 1976 was alumino-silicate-(poly)acrylic acid (ASPA), and this was designed to fit into this category. Actually, it was not particularly aesthetic, and the instructions for use were vague and inaccurate, and this led to poor clinical handling and a relatively high failure rate. Fortunately, it was not long before two of the manufacturing companies developed modifications with notably improved translucency and higher physical properties. The main problem with ASPA, and even with the two new products, proved to be the relatively slow setting mechanism, which left them very susceptible to variations in the water balance for at least the first hour after placement (Mount 1981). The profession proved to be rather impatient with materials that were intolerant of poor handling, and it was quite a while before their popularity was established. It was not until an efficient method of sealing them against water exchange was developed that a successful outcome could be guaranteed for each restoration (Earl et al, 1989) (Figure 4.1) and they found their niche within operative dentistry.

The problem of maintenance of water balance led to the development of a resin-modified form of glass-ionomer as an alternative (Mitra 1994). The main difference is the addition of further resins and photo-initiators to the auto cure materials so that they can be light-cured on command immediately after placement in the cavity. The two phases will cross-link, and this apparently has no untoward effect on the normal acid–base auto cure setting reaction, which continues as usual; but it does provide an immediate resistance to early water uptake. There is clinical convenience in this, because the restoration will have a moderately stable water balance

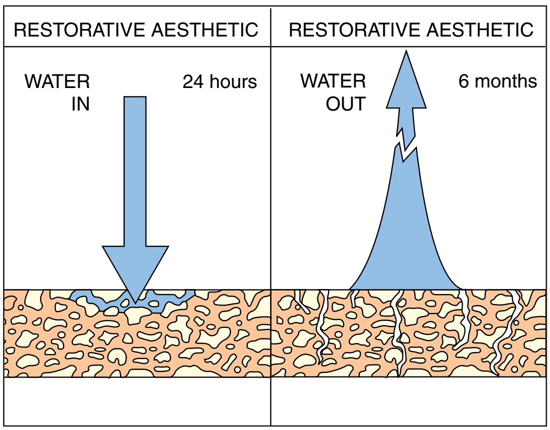


Figure 4.1

Diagram illustrating the water balance of the auto cure Type II.1 restorative aesthetic glass-ionomers. Note that water uptake is a serious problem in the early stages following placement. Water will penetrate through the entire depth of the restoration very rapidly and downgrade both physical properties and, more importantly, translucency. It is also important to be aware of the potential for water loss for up to 6 months after placement.

immediately, and can be contoured and polished as soon as it is set. However, it must not be forgotten that these resin-modified materials will take up water over time and show a degree of expansion. Also, they will still remain subject to dehydration in the short term if they are left exposed to air for any length of time.

The usual ion-exchange adhesion to both enamel and dentine is available with both varieties, and biocompatibility is of a high order, which means that pulp irritation is essentially not a problem. The release of fluoride and other ions is similar and is a major advantage, and there have been only minor anecdotal reports of microleakage or recurrent caries. However, it must be emphasized that no restorative material will, in itself, be proof against recurrent caries or – as it should rightly be identified – continuing disease, and long-term survival of restorations will only be recorded in the presence of good preventive dentistry.

Clinical handling is no more demanding than that for any other restorative material, and it is only necessary that both the operator and the chairside staff pay full attention to the manufacturers' instructions. Capsulation and machine mixing is the best way of standardizing clinical procedures, and long-term stability in the oral environment has been proved in well-conducted practices (Tyas 1983; Mount 1986, 1997).

The physical properties of the resin-modified materials are generally better than the auto cure materials, with resistance to the shear/punch test being increased by up to 50% (see Figures 1.7 and 1.8). Also, translucency and colour matching are improved.

However, the original auto cure materials remain very useful, even though it may be a little harder to achieve first-class results in the clinical environment (Figures 4.2 to 4.15). The main difficulty is that, to produce a material that will allow development of the best translucency, it is necessary to reduce the fluoride content and to have a material that will mature slowly. The problem then is that the restoration must achieve an advanced level of maturity before being exposed to the oral environment. This means there must be a protective coating placed over it to prevent alterations

Placement of type II.1 auto cure

Figure 4.2

Erosion lesions are present at the gingival margins of the upper-right lateral incisor and canine. They will be restored with an auto cure glass-ionomer.

Figure 4.3

Prior to cleaning the teeth, soft-tin matrices (Hawe no. 720) are bent to form and tested against the teeth to ensure an accurate fit.

Figure 4.4

The lesions are cleaned with a slurry of pumice and water for 5 seconds only. The pumice is then flushed away and the tooth lightly dried.

Figure 4.5

10% poly(acrylic acid) can now be applied and left for 10–15 seconds before washing and drying lightly. Dehydration should be avoided.

Figure 4.6

The selected shade of cement is now syringed into place and the matrices positioned and left undisturbed while the cement sets. At 4 minutes from the start of the mix, the excess cement can be tested for degree of set and then broken away to clear the margins.

Figure 4.7

As each matrix is removed, the cement is immediately covered with a generous layer of an unfilled, light-activated bonding resin. Further trimming can be undertaken through the bond, and more bond applied if necessary.

to the water balance for some time after placement. Methods of developing a fast-set cement, such as removal of excess calcium ions from the surface of the glass particles or modification of the thermal history of the glass, will reduce the potential for translucency of the restoration, and are therefore unacceptable in this group.

Some manufacturers claim that their Type II.1 material is sufficiently mature at 15 minutes to accept contouring and polishing. The immediate effect of carrying out these procedures, under air/water spray, within that time-span may not be immediately noticeable. However, in the long-term, the restoration will not develop full translucency and the result will generally be disappointing.

The answer lies in allowing the cement to mature under a waterproof sealant for a minimum of 24 hours before challenging the cement with the possibility of water exchange – either in or out. It is a simple clinical procedure to apply a very-low-viscosity, light-activated resin sealant immediately after removing the matrix and then delaying polishing for 24 hours or more. The results fully justify the additional time involved.

There has been an unfortunate tendency lately to try to develop a restorative material that can be contoured and polished immediately after insertion. It has been claimed that time is at a premium and that patients will not tolerate a request to return for a further assessment and polishing appointment. However, it is suggested that it is always desirable to review any restoration at a later date to re-assess the occlusion, check the contour and see that the colour match is adequate. None of the currently available plastic aesthetic restorative materials can achieve maturity immediately, so it seems logical to allow time before assessing the final result of any restoration.

The autocure and the resin-modified materials are very similar in most aspects, and their detailed properties will therefore be discussed together.

Significant factors

Powder–liquid ratio

Powder–liquid ratio varies among the materials currently available, from approximately 2.9:1 to 3.6:1, for materials using hydrated poly(alkenoic acid) as the liquid, up to as high as 6.8:1, for the anhydrous types. The inclusion of the dehydrated poly(alkenoic acid) within the powder accounts for the apparently high powder content. The proportions are similar for the resin-modified materials. Within limits, the higher powder content leads to higher physical properties. The translucency of the ultimate restoration is, to a large extent, related to the thermal history of the glass during manufacture, as well as to the fluoride concentration and the powder particle size. The glass utilized in the restorative aesthetic cements has a lower fluoride content, but the setting time remains clinically acceptable, and translucency can be achieved with correct handling. A reduction in the powder content may marginally increase translucency, but will at the same time lead to a reduction in physical properties. Conversely, it is possible to increase the powder content to such a degree that not all the particles will be completely reacted with the liquid, and this, of course, will result in a reduction of translucency as well as physical properties.

Dispensing the powder and the liquid in a capsulated system that is machine-mixed and where the capsule then converts to a syringe is desirable, since the end-result will be standard and predictable. Mixing time is considerably reduced, but working time does not alter because there is a slight temperature increase during mixing. This temperature increase tends to encourage a snap set. Placement with a syringe will assist in adaptation to the floor of the cavity and minimize the incorporation of further voids, and the porosities will be relatively small and evenly distributed.

It is difficult to measure a standard quantity of both powder and liquid when attempting to mix by hand unless both materials are weighed on a balance. There will also be incorporation of relatively large porosities during hand mixing, and placement into the cavity with a small instrument will tend to aggravate the situation. It is possible to hand mix and then collect the cement into a disposable syringe; but this is rather cumbersome and time-consuming, particularly since working time with these materials is generally relatively short.

Time to mature

Auto cure cements

As has been discussed above, this group of aesthetic glass-ionomers remains slow-setting, with

a prolonged chemical reaction occupying a period of several days, possibly months. This property cannot be altered or speeded up without reducing the translucency. There is an initial snap set at approximately 4 minutes from the start of mix, at which time it is possible to remove the matrix and examine for successful placement. However, at this point it is extremely susceptible to water uptake and water loss. It is therefore essential to keep the restoration completely covered, immediately after removal of the matrix, with a waterproof sealant that should remain intact for as long as possible to allow full chemical maturation before exposure to the oral environment (Figures 4.2–4.9).

Manufacturers supply special varnishes as sealants, but, because most of these contain an evaporative vehicle, they remain porous to some degree, thus allowing a water exchange both in and out. If these varnishes are to be used, they should be placed in two layers and dried carefully, with a gentle play of compressed air, after each application for a period of approximately 30 seconds.

It has been shown that the most effective sealant is a single-component, very-low-viscosity, light-activated, unfilled bonding resin (part of the composite resin system), which has been vacuum-packed and is therefore free of porosities (Earl et al, 1989) (see Figure 1.25). This should be allowed to flow over the restoration in a generous layer immediately the matrix is removed. The restoration can be trimmed as necessary through this layer. When the contour is satisfactory, further resin bond may be added as required and, only then, should be light-activated. This will produce a complete seal for at least an hour. Water exchange may occur very slowly over the next 24 hours, at which time the resin sealant can be removed and the restoration polished under air/water spray, even though it may be a full 7 days before optimum translucency and colour match is achieved (see Figures 1.44, 1.45).

The cement should not be challenged with dehydration for at least 6 months after placement. If it is necessary to expose an immature restoration

Figure 4.8

The resin is light-activated. Note that there is likely to be a small amount of excess resin at the gingival margin, which may act as an overhang. This should be removed with a sharp blade prior to releasing the patient.

Figure 4.9

The finished restorations, 14 years after placement.

Figure 4.10

A proximal composite resin restoration has changed colour and shows signs of marginal leakage. It needs to be replaced.

Figure 4.11

A lingual view of the restoration shown in Figure 4.10. The marginal leakage and colour change are more apparent.

Figure 4.12

The old restoration has been removed from the cavity. There may be a little demineralized dentine left on the floor, but as a glass-ionomer is to be placed there is no need to remove it completely.

Figure 4.13

On completing the cavity, 10% poly(acrylic acid) is applied for 10–15 seconds, and then washed thoroughly with air/water spray.

Figure 4.14

The lingual view of the completed restoration. A Type II.1 restorative aesthetic glass-ionomer is the material of choice because of the ion-exchange adhesion and the potential for remineralization.

Figure 4.15

The labial view of the same restoration. The glass-ionomer was covered with a low-viscosity resin bond immediately upon removal of the matrix.

during this period, it should be protected again with a further application of either the resin bonding agent or the varnish for the time that it is exposed (see Figure 1.41).

Resin-modified materials

Immediately after light-activation, the restoration will be sealed against water exchange to the full depth of the light penetration. This will vary depending on the colour of the cement, the efficiency of the activator light and the length of time of light-activation. Any remaining glass-ionomer not affected by the light will continue to undergo the acid–base setting reaction, but at a slightly reduced rate, in a similar manner to the normal auto cure materials until the entire restoration is fully mature. Any of the polymer content that remains unreacted by the light will auto cure over a short period of time because of the presence of the reduction/oxidation (redox) component. Both the glass-ionomer and the auto cure resin component will continue to mature for at least one week and maybe longer. However, it should be noted that the materials set by light-activation will be superior in physical properties to any of the auto cured aesthetic glass-ionomers. This means that, particularly in a deeper cavity, incremental build-up is always desirable.

Most manufacturers claim that a 20-second exposure to the light is sufficient; but often the light cannot be placed in close proximity to the restoration because of the presence of a matrix. As it is not possible to overexpose the restoration to the activator light, it is generally wise to allow a minimum of 40 seconds for a small restoration and longer for larger ones. Some manufacturers offer a resin glaze to be painted over the finished restoration after contouring and polishing. This will have no effect on the continuing maturation, but will seal any voids or porosities exposed by the recontouring procedures and leave a smooth surface (Figures 4.16–4.25).

Placement of resin modified glass-ionomer

Figure 4.16

Extensive erosion lesions on the buccal surfaces of the upper-right canine and first bicuspid. They will be restored with a resin-modified glass-ionomer. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

Figure 4.17

The lesions were gently scrubbed with a slurry of pumice and water on a rubber cup, and then washed and dried lightly. As the gingival tissue was slightly abraded during the scrub a drop of trichloracetic acid was applied for haemostasis (see Box C, page 85). The cavity was then conditioned with 10% poly(acrylic acid) for 10–15 seconds, washed and dried lightly. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

Figure 4.18

Before mixing the cement, select the appropriate translucent matrix (see Box E, page 182), and test it for fit. Adjust it as required. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

Figure 4.19

Mix the cement (capsulated for preference), syringe to place and position the matrix. Light-activate for 20 seconds through the matrix. Remove the matrix, and immediately light-activate for a further 20 seconds at least. The restoration can now be contoured and polished with fine diamonds under air/water spray. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

Figure 4.20

The restorations immediately after the initial contouring prior to releasing the patient. The restorations have been sealed with a low-viscosity resin to eliminate surface porosities and roughness resulting from the contouring. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

Figure 4.21

The restorations 1 year after placement. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

Figure 4.22

There is a root surface carious lesion on the proximal of the upper-right central incisor. It will be restored with a resin-modified glass-ionomer.

Figure 4.23

The cavity has been conservatively prepared to develop a clean margin around the full circumference, but leaving some demineralized dentine on the axial wall.

Figure 4.24

The cavity is conditioned with 10% polyacrylic acid for 10 seconds only then washed and dried lightly.

Figure 4.25

The completed restoration, showing an acceptable colour match immediately before removal of the rubber dam. The translucency will improve over the next seven days.

Adhesion to enamel and dentine

Chemical union with underlying tooth structure is one of the greatest advantages of the glass-ionomers. It means that an erosion lesion does not need to be instrumented, and a carious cavity does not require the traditional mechanical undercut design for retention. There will be no microleakage and, in conjunction with the release of fluoride and other ions, there will be the potential for remineralization and the prevention of recurrent caries (see Chapter 2). The smear layer and other surface contaminants left following cavity preparation should be removed with a 10–15 second application of 10% poly(acrylic acid). The lesion should be washed thoroughly with air/water spray and then dried gently, but not dehydrated, and the cement should be placed immediately.

For the erosion/abrasion lesion where no cavity preparation has been undertaken, it is desirable to remove any plaque or pellicle first by lightly scrubbing with a slurry of pumice and water for 5 seconds (Figure 4.4). This should be washed off and the area should be lightly dried, leaving a surface completely free of contaminants and in a condition to accept the chemical union between the restorative material and the tooth.

Release of fluoride and other ions

Following successful placement and polishing of the glass-ionomer, there will be a high rate of fluoride release for a period of 6–12 weeks thereafter, which can be traced into surrounding and adjacent tooth structure. The fluoride release has been measured as continuing at a steady level for a further 8 years and probably longer (Forsten 1998), and it is postulated that the calcium (strontium) and phosphate exchange will follow a similar pattern. In the presence of professional or home-applied topical applications of fluoride, and routine use of a fluoride-containing toothpaste, a fluoride balance will develop with the cement, and a continual flow can be predicted. There is a

BOX C TRICHLORACETIC ACID

The profession has a need for efficient methods of haemostasis. Trichloracetic acid is not new, but has not been popular or routinely used for some years now. However, it is a very safe and reliable method of controlling haemorrhage in areas of local tissue damage, with virtually no side-effects (see Figures 4.17 and 4.27). It is highly caustic but self-limiting, and therefore does not penetrate far into soft tissue. The resulting eschar separates from the subjacent tissue without producing an inflammatory response, and healing is rapid and uneventful. It will effectively arrest gingival haemorrhage, and will remove granulation tissue to a limited extent only.

- Purchase in crystal form.
- Leave the top off the bottle for a few hours and the crystals will deliquesce, leaving a liquor of concentrated trichloracetic acid.
- Handle with care.
- When required, dispense 2 or 3 drops with a glass pipette into a Dappen's dish.
- Touch the blade of a no. 6 flat plastic instrument or similar into the liquid and convey this to the appropriate place on the soft tissue. Do not apply more than this quantity at any one time. Local anaesthesia is not required.
- The effect will generally be immediate, with an eschar formed within 30 seconds. Repeat as necessary.
- Wash thoroughly with water.

Wolfort FG, Dalton WE, Hoopes JE, Chemical peel with trichloracetic acid, *Br J Plastic Surg* (1972) **25**: 333–4.

Heithersay GS, Tissue response in the rat to trichloracetic acid—an agent used in the treatment of invasive cervical resorption, *Aust Dent J* (1988) **33**: 451–61.

notable lack of plaque accumulation on glass-ionomer restorations, at least in part, because of the fluoride release, and tissue tolerance is therefore high (see Figures 1.68, 1.69).

Pulp compatibility

Pulp tolerance to the glass-ionomers has been reported by several authors to be very high, and clinical results substantiate this (Wilson & McLean 1988). Dentine is a very efficient buffer in itself, and the large, complex molecular chains of poly(alkenoic acid) cannot penetrate to any great depth. Recent studies show a mild initial inflammatory response within the pulp tissue, arising from a newly placed glass-ionomer, which resolves quite rapidly over a few days. Dentine bridging has been shown in animal studies, following closure of a mechanical exposure of an otherwise healthy pulp with a glass-ionomer (Cox & Suzuki 1994). This suggests that there is no need to place a sub-lining of another material, such as calcium hydroxide, prior to placing a properly mixed glass-ionomer. In fact, the presence of another material will reduce the effective area for adhesion and will be more of an interference than an advantage.

Figure 4.26

There have been porcelain crowns on the lower-right canine and the second bicuspid as part of a three-unit bridge for approximately 15 years. There are now quite deep erosion lesions at the gingival margins of both abutment teeth. The lesion at the gingival of the second bicuspid, possibly an abfraction lesion, extends approximately 2 mm subgingivally, so a minor gingivectomy needs to be carried out.

Figure 4.27

Using electrosurgery, approximately 2 mm of gingival tissue was removed to expose the gingival margin of the erosion lesion. As there was a minor amount of haemorrhage in the gingival tissue following electrosurgery, a very light application of trichloracetic acid (see Box C, page 85) has been applied to control the haemorrhage. This produces instant haemostasis, and will repair readily, since the acid is self-limiting.

Figure 4.28

The two lesions are washed and lightly dried and then 10% poly(acrylic acid) is applied for 10–15 seconds to condition the surface ready for the ion-exchange adhesion. The teeth are washed thoroughly again and dried, but not dehydrated.

Figure 4.29

Hawe matrices no. 721 have been preformed, the cement syringed to place and the matrices adapted to position.

Figure 4.30

At approximately 4 minutes from the start of the mix, excess cement can be tested for degree of set and removed prior to lifting the matrices. Immediately the matrices have been removed, a generous layer of a very-low-viscosity, light-activated resin bonding agent is applied to seal the surface against changes in the water balance.

Figure 4.31

The excess glass-ionomer has been recontoured and a further coat of bond has been applied and light-activated.

Figure 4.32

The finished restorations one week after placement and contouring, showing the soft tissue has healed well over that period.

Figure 4.33

The finished restorations, 18 years after placement.

Figure 4.34

The incisal edge of the lower-right canine is deeply eroded. However, there is a complete wall of enamel surrounding the entire erosion lesion, so that the restoration will be well supported against lateral and shear stresses.

Figure 4.35

Because of the depth of the lesion, it is not possible to scrub with pumice and water, so it is conditioned with 10% poly(acrylic acid) for 10–15 seconds only. The area is washed thoroughly and dried lightly, but not dehydrated.

Figure 4.36

A Hawe matrix no. 722 is preformed, the cement applied and the matrix repositioned.

Figure 4.37

At approximately 4 minutes from the start of mix, the excess cement was tested for set and broken away prior to lifting the matrix. The restoration was immediately sealed with a very-low-viscosity, light-activated resin bonding agent. The restoration is shown immediately after the rubber dam has been removed and the occlusion adjusted.

Figure 4.38

The erosion lesion on the occlusal of the lower first bicuspid was restored with a glass-ionomer about 8 years prior to the photograph. There has been some loss of the glass-ionomer, but the erosion is stable.

Figure 4.39

Three similar restorations 7 years after placement.

Figure 4.40

An old cervical composite resin restoration at the gingival of a lower right canine. The lesion extends around the distal to join up with a failing cermet cement restoration at the lingual–gingival margin.

Figure 4.41

The same lesion viewed from the lingual and distal aspects. A temporary restoration of zinc oxide and eugenol has been placed in the distal part of the lesion and is also breaking down.

Figure 4.42

The completed cavity viewed from the labial aspect. Note that the margins have been carefully cleaned, but on the axial wall there is still some demineralized dentine.

Figure 4.43

The completed cavity, showing the distal and lingual extension. There is some affected dentine left on the axial wall, which will not be removed.

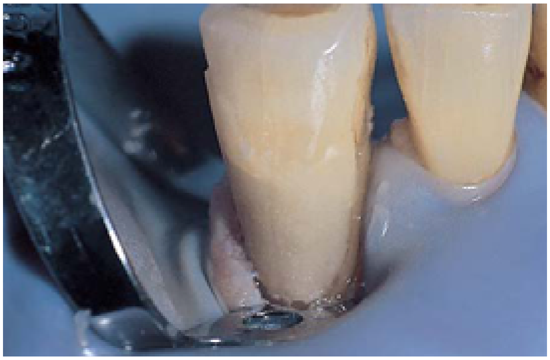


Figure 4.44

The cavity has been restored using a resin-modified glass-ionomer, which was placed in three increments. A small amount of cement was syringed into the lingual extension and light-activated. The distal section was restored next, and finally the labial section.

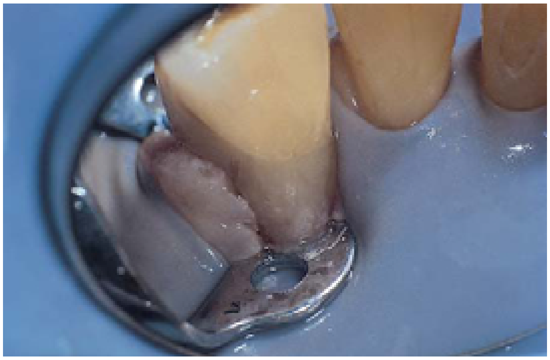


Figure 4.45

Each increment was light-activated for 20 seconds, and the final restoration was exposed again to the light for a further 20 seconds from each of three directions.

Figure 4.46

The finished restoration 6 months after placement, viewed from the labial aspect. Note the satisfactory gingival response.

Figure 4.47

The lingual view of the restoration after 6 months. The patient is applying fluoride daily in a small plastic ‘pull down’ splint to control root-surface caries.

Physical properties

The physical properties of both the resin-modified and the auto cure materials are largely dependent upon the powder–liquid ratio at which they are mixed. This means that materials dispensed in capsules and machine-mixed will generally be superior to those that are handmixed. The physical properties of the resin-modified materials, as measured by the shear/punch test, are close to those of a micro-filled composite resin. Fracture resistance is still not sufficient to build a marginal ridge or restore an incisal corner, but they are capable of withstanding some occlusal load, providing the restoration is well supported by surrounding tooth structure. They are also radiopaque and therefore suitable for the restoration of inter-proximal lesions, which may have to be monitored radiographically.

The auto cure materials are not quite as strong, but their clinical history shows that they are very useful except under heavy occlusal load. Because of the continuing setting reaction as well as the ion-exchange from the surface of a restoration there is a continuing maturation within the restoration. Both strength and abrasion resistance will therefore improve over time, and this will in part account for the reported longevity shown in a number of studies. Most of the early materials were radiolucent, and were best confined to anterior teeth only. The current versions are nearly all radiopaque. Abrasion resistance is the one property that can be properly tested only in the oral environment. The auto cure materials have a long history showing high resistance to abrasion, but it is not possible simply to transfer this history to the resin-modified materials. Recent experience suggests that the small amount of water uptake arising from the presence of the HEMA will, in fact, reduce resistance to wear, and there are reports of minor colour shifts as well, probably for the same reason.

Longevity

This is always a serious question in relation to any of the restorative materials, and there has been considerable research carried out over the years. Very often the most significant factor is overlooked, and research papers are written based upon a patient base that is unsuitable for studies in longevity. There is no question that caries is a disease based upon a bacterial infection, and therefore no surgical technique designed to cure it will be effective and no restorative material *per se* will be capable of eliminating it. This means that true estimation of the capabilities of a material can only be carried out in a situation where continuing disease is not a factor.

Many of the restorations cited in this text have been in place for a substantial number of years. The patients have been loyal to the practice, and their caries risk factor has been zero for all of those years. This is not to say that the situation will not change as they join the echelons of the ageing; but they are expected to present themselves periodically for review and advice to make sure they do not later suffer the problems of root surface caries and periodontal disease.

The last few illustrations (Figures 4.48–4.53) show selected cases from the files of the author, and some of these cases appear elsewhere in this text. It has been shown that the wear factor of the newly placed glass-ionomer is reasonably high. However, there is no doubt that, as it matures, the surface will become steadily more heavily mineralized, and, in the absence of a heavy occlusal load, it will withstand the rigours of the oral cavity very well indeed. It will be interesting to follow the newer versions of this material, because the physical properties have been substantially improved. It is likely, therefore, that a satisfactory longevity can be assumed – in the absence of disease.

Figure 4.48

These are two of the original ASPA restorations placed in 1978 and photographed 20 years later. They were not properly sealed and protected at the time of placement, but in spite of this they have survived well.

Figure 4.49

A large erosion lesion on the buccal surface of the upper molar was restored with an auto cure glass-ionomer and properly sealed with a resin sealant.

Figure 4.50

The same restoration shown in Figure 4.49 photographed 12 years after placement. Note the satisfactory maintenance of both colour and form.

Figure 4.51

Erosion lesions on two upper bicuspids were restored with different glass-ionomer materials in 1981. Note that there is a slight variation in degree of translucency.

Figure 4.52

The same restorations shown in Figure 4.51 photographed in 1992 – eleven years later. Note that the colour and contour of both have been maintained satisfactorily.

Figure 4.53

An erosion lesion at the gingival margin of the crown on the lower-right first bicuspid was restored with an auto cure glass-ionomer 16 years ago. There has been very little change over that period – compare with Figure 1.68, showing the same restoration at 5 years.

5 Type II.2: Restorative materials

Description

To encompass recent developments, this category of glass-ionomer materials has been broadened and the name has been modified by the removal of the word 'reinforced' from the title. The profession is constantly seeking increased strength in the glass-ionomers, and a number of improvements have been evolved since the beginning. As has already been noted, they generally lack fracture resistance, and this limits their application in the oral cavity. Several methods have been tried in the past in an attempt to improve this particular property, but, until recently, none of them have made a significant difference. However, in recent times there have been a series of modifications available with notably improved fracture strength, and it is likely that there will be further increases in the near future. Fortunately, most of these newer materials have retained the colour match with tooth structure as well as the ion-exchange adhesion and ion migration. Further research may even improve on these aspects. This group of materials are all in the fast-setting category; but it must be noted that they remain susceptible to dehydration for some time after placement (Figure 5.1).

The following materials were developed in the early days of glass-ionomers and marketed as 'reinforced'. However, this was essentially a misnomer, because their physical properties were not significantly improved over the other types. Wear resistance was improved; but generally both adhesion and fluoride release were reduced. The expectations of them were rather high, but not entirely fulfilled, and they needed to be covered with another material if aesthetics was important.

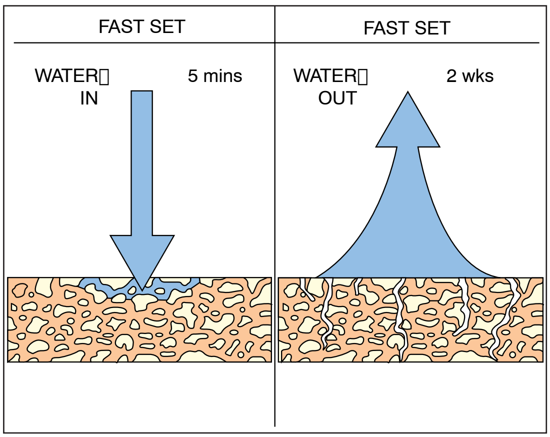


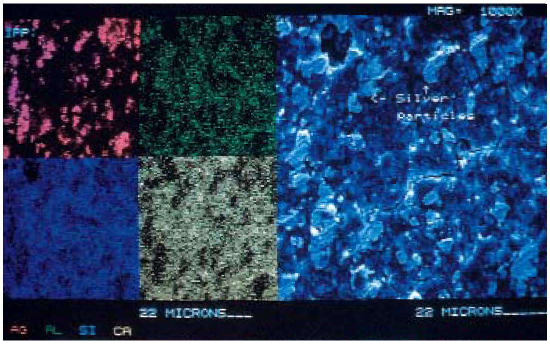
Figure 5.1

Diagram showing the water balance of the Type II.2 glass-ionomers. As they are fast-setting, they are resistant to water uptake in about 5 minutes from the start of mix. This means that they can be polished shortly after removing the matrix. However, if they are left exposed to air for any length of time in the first 2 weeks, they are liable to lose water and crack.

Silver cermets

Probably the most widely used material was the so-called 'silver cermet' (Thornton et al, 1986). This was manufactured by incorporating approximately 40% by weight of micro-fine silver particles, less than 3.5 μ in diameter, in with the powdered glass particles (McLean and Gasser 1985). The two were then sintered together under pressure. Unreacted silver was washed out and up to 5% of titanium dioxide included to modify the colour. The glass particles produced by this method were covered with a fine layer of metallic silver (Figure 5.2) and were generally more rounded than in other glass-ionomers (Figure 5.3). This led to improved handling properties, with the potential for high density and low porosity in the finished restoration. The presence of the silver on the surface of the particles allowed for a significant improvement in abrasion resistance, and the surface could, in fact, be burnished. Compressive strength and fracture resistance were also improved to a limited extent. Rebuilding of marginal ridges in large restorations was not advocated, although where the occlusal load was not high they survived well (Figures 5.4, 5.5). They were once advocated as a core build-up material, but their limited fracture resistance means that their use should be limited to modifying relatively minor deficiencies rather than providing an entire core (De Wald et al, 1990). Reinforcement with pins and posts will not compensate for the low tensile strength, so there should be at least 2–3 mm of sound tooth structure forming the entire gingival cuff of a preparation for a crown (Figures 5.6–5.13).

Adhesion to dentine and enamel appear to be slightly reduced, probably because of the presence of the silver particles; so it is generally



Clinical placement

Figure 5.2

A micro-analysis of a cermet material showing the approximate constituents, particularly the silver content. Note that the silver is finely distributed over the surface of each powder particle, thus enhancing wear resistance.

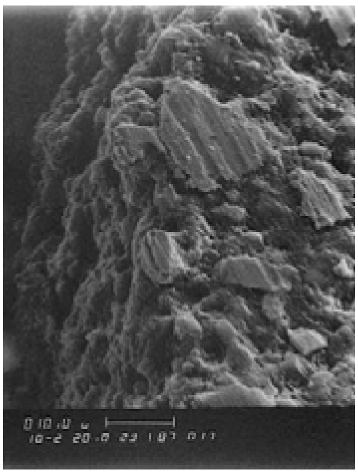


Figure 5.3

A scanning electron micrograph of the surface of a cermet cement showing the rounded outline of the individual powder particles. The silver particles are not obvious. Original magnification ×1000.

Figure 5.4

A failed amalgam restoration in an extensive occluso-proximal cavity has been replaced with a cermet material.

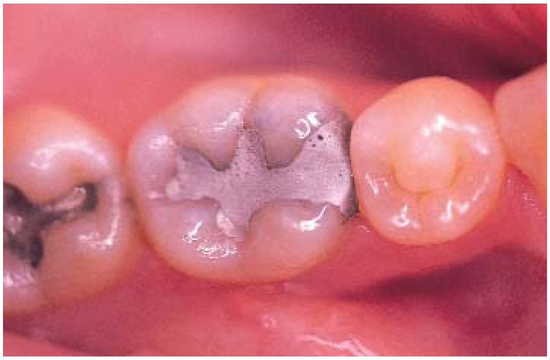


Figure 5.5

The same restoration photographed 14 years after placement shows that the material has survived very well. It is not recommended that a cavity of this size should be restored with this material; but if the wear factor in the particular patient is low then it may be satisfactory.

Core build-up for crowns

Figure 5.6

The upper-right first and second bicuspids were both broken in a motor vehicle accident. Buccal and lingual cusps were lost from the first bicuspid and buccal cusp only from the second, and both required root-canal treatment.

Figure 5.7

The root canals in both teeth have been obturated and the remains of existing restorations removed.

Figure 5.8

Stainless steel posts have been cemented into both teeth. The posts in the first bicuspid protrude beyond the remaining tooth structure because it was anticipated that the core would be built up to that level. The posts in the second bicuspid were cut off to just below the proposed core height, because the entire lingual cusp was still present and would provide support. Remaining tooth structure was conditioned with 10% poly(acrylic acid), and then washed thoroughly and dried, but not dehydrated.

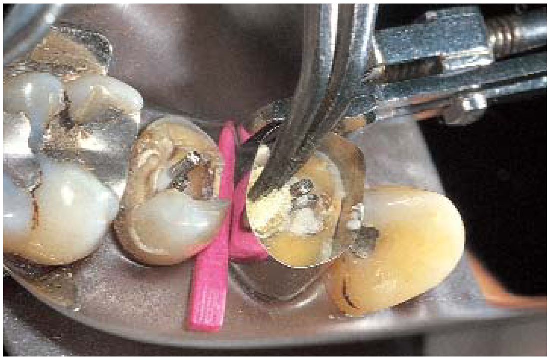


Figure 5.9

A standard metal matrix has been placed on the first bicuspid and a cermet cement has been syringed into place incrementally. Each increment was tamped into place with a small plastic sponge (see Figure 8.18) to ensure full adaptation to underlying tooth structure and around the two posts.

Figure 5.10

The build-up on the first bicuspid is complete and the matrix removed. However, since this was to remain isolated and dry for a period while the second bicuspid was restored in the same way, the freshly placed cermet was covered with a generous coating of a very-low-viscosity, light-activated bonding resin to prevent water loss in the short term.

Figure 5.11

The cermet cement core has now been built up on both teeth.

Figure 5.12

The labial aspect of the completed preparations which were carried out at the same visit.

Figure 5.13

The lingual view of the preparations. Note the amount of natural tooth structure incorporated within the preparations.

wise to incorporate some element of mechanical interlock in the cavity design. It is a fast-setting cement with early resistance to water uptake, but it remains subject to dehydration for at least 2 weeks after placement. Many restorations show fine surface cracking and crazing later as they mature, although these do not appear to propagate over time.

It has been used frequently in situations where aesthetics is not significant (Figures 5.14 to 5.17), and is also of value where it can be laminated and supported with another material (Figures 6.10 to 6.17). Probably its position of greatest value lies in repairing chipped and faulty margins of existing restorations, particularly amalgam, as an alternative to full replacement (Figures 5.18 to 5.20).

Because of the presence of the silver, this material has the same radiopacity as amalgam, but it is closer to tooth structure in colour (Figure 5.21). It has been widely used in situations where aesthetics is not important and the rapid set, early resistance to water uptake and abrasion resistance can be of value. Wherever it is placed, it must be well supported by remaining tooth structure and there should be some degree of retention in the cavity design. It still has a wide market and, as long as the above restrictions are noted, it remains a useful material.

Amalgam alloy admix

An alternative method of improving physical properties was to incorporate spherical amalgam alloy particles with a fast-setting glass-ionomer powder (Simmons 1983). The amalgam alloy was incorporated in the proportion of 8 parts cement powder to 1 part alloy by volume, and this was then mixed to a suitable consistency with poly(acrylic acid) at a ratio of approximately 3:2 by weight (Figures 5.22, 5.23). The resultant cement was quite black, and therefore generally needed to be covered by another material to overcome the aesthetic challenge (Figures 5.24, 5.25). However, the physical properties were slightly improved over

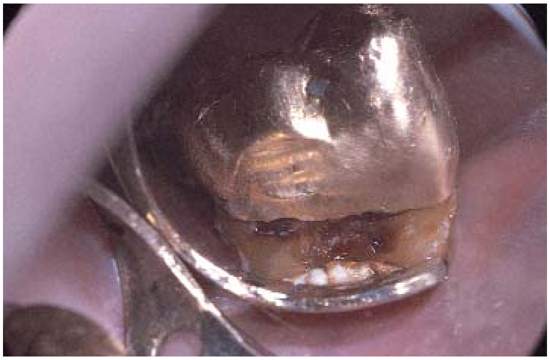


Figure 5.14

There is root-surface caries beyond the gingival margin of a gold crown on a lower-right molar.

Figure 5.15

The caries has been removed and a limited amount of retention has been placed at the gingival and occlusal margins.

Figure 5.16

The cavity has been conditioned with 10% poly(acrylic acid), and the cement syringed to place and positively adapted with a matrix.

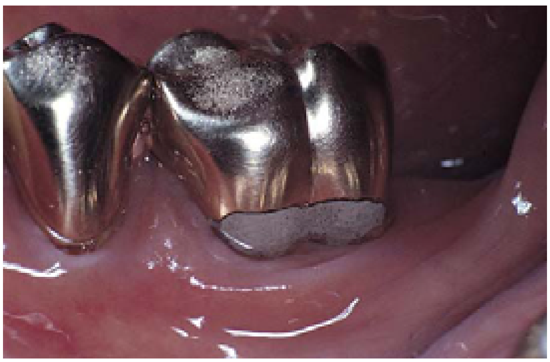


Figure 5.17

Before removal of the rubber dam, the excess cement was trimmed at intermediate high speed under air/water spray. After removal of the dam, the restoration was polished with abrasive rubber points under air/water spray. It was photographed approximately five years after placement.

Figure 5.18

There has been a limited failure of enamel from the mesio-lingual cusp of an upper molar. As the occlusal load is still borne by the amalgam as well as by the disto-lingual cusp, a minimal cavity was prepared. The amalgam was dressed back and a small amount of retention was included.

Figure 5.19

The completed restoration photographed at the time of restoration

Figure 5.20

A similar repair on an adjacent tooth using a cermet cement. It was photographed 8 years after placement.

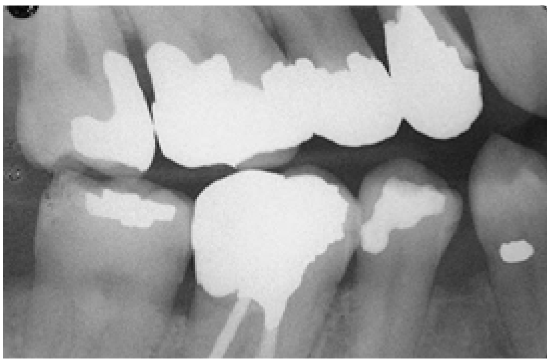


Figure 5.21

Both the upper and lower first molars have been restored with an amalgam laminate over a cermet base, and the tunnel in the lower second bicuspid is also a cermet. Note that it is not possible to differentiate radiographically between the two materials.

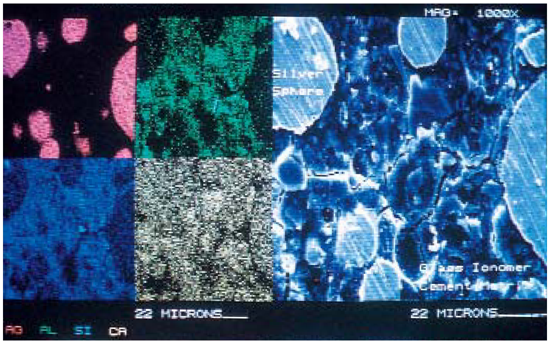


Figure 5.22

A micro-analysis of an amalgam alloy admix material. Note the large spherical amalgam particles, which will have little or no union with the surrounding glass-ionomer.

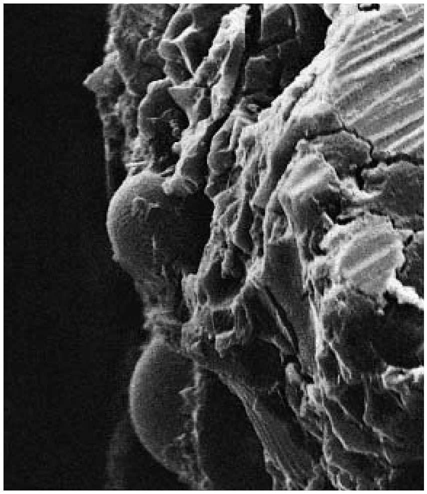


Figure 5.23

A scanning electron micrograph of a broken piece of an amalgam alloy admix specimen. Note the separate alloy particles left exposed by the fracture. Original magnification $\times 1000$.

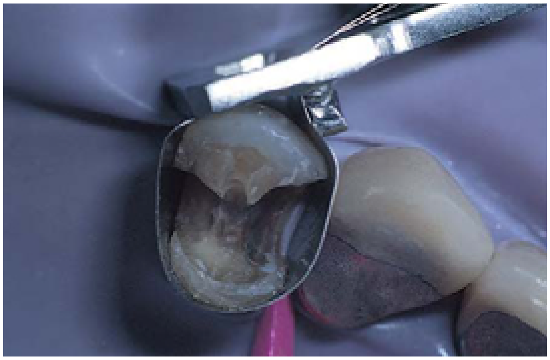


Figure 5.24

An upper bicuspid has had a failed amalgam removed, revealing a split cusp. A full crown is to be prepared, so the cavity is about to be restored with an amalgam alloy admix to simplify the crown design.

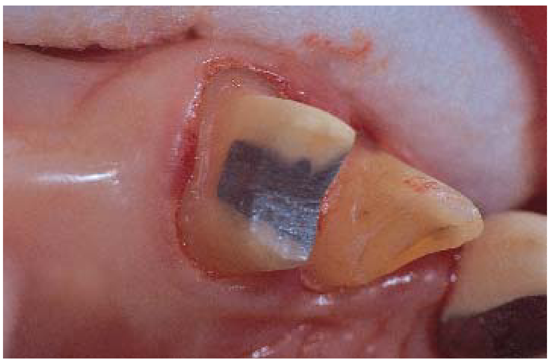


Figure 5.25

The amalgam alloy admix has been placed and the crown preparation carried out immediately. Note that the glass-ionomer remains undisturbed in spite of the preparation.

the standard cement, particularly in abrasion resistance. It set rapidly and showed an early resistance to water uptake, so that, when used as a core build-up, further preparation could be carried out immediately it was set. Adhesion to underlying tooth structure and fluoride release were both acceptable, but less than with the unfilled materials. It was difficult to mix to the prescribed consistency by hand, but it eventually became available in capsules, so handling properties improved. However, in view of its colour and the limited improvement in physical properties it offered, it must be regarded as having limited application, and its market has fallen considerably.

Silver alloy admix

A further alternative along similar lines was to include a silver-containing alloy in flat broken pieces rather than spheres, on the assumption that the flakes would offer a larger surface area for reaction with the poly(alkenoic acid). One company used an alloy composed of 50% silver, 22% copper and 28% tin, and the powder–liquid ratio was approximately 2:1 by weight or 8:1 by volume. Its proponents claimed a higher abrasion resistance because, when subject to wear, the preparation developed a Bielby-type smear layer on its surface.

Certainly its physical properties, as measured by the shear/punch test, were superior to those of either of the above materials, and the colour was a little lighter than the cermet cement. The fluoride release and adhesion to tooth structure were both acceptable; but the material has always had a limited market.

New generation high-strength glass-ionomers

Over the last few years there have been a number of innovations leading to a new generation of fast-setting, high-strength materials with early resistance to loss of water balance. They are all auto cure materials, and the shear/punch test suggests that their physical properties are 10–15% better than those of the resin-modified materials. As a result it must be said that the materials listed above have all been outdated. No doubt some of them will continue to have a market, and, as long as their limitations and the improvements in the new materials are recognized, they will do no harm.

There are a number of sub-titles offered for the new materials, ranging from ‘condensable’ to ‘high-strength’ and they have been further subdivided by speed of set. This means that they can be available as a ‘normal set’ or as a ‘fast set’ version, where the sole difference is, in fact, the shorter working time and setting time. The physical properties remain essentially the same, regardless of setting time, and the operator must be aware that the faster materials should not be regarded as universal for all circumstances.

All these materials are tooth-coloured, and some of them incorporate a degree of translucency that, while acceptable, is not as great as that of the Type II.1 materials. They are all available in a range of shades for colour matching, and they are particularly useful as transitional restorations to stabilize a situation while the caries index is reduced to manageable levels (Figures 5.26–5.33). With a little care, they can be entirely acceptable for the restoration of anterior or posterior teeth in situations that are not a serious aesthetic challenge (Figures 5.34–5.41).

It is interesting to note that the main source of improvement has been through the refinement of powder particle size and particle size distribution, and this closely relates to the composite resins. There have also been changes in the heat history of the glass, and this has led to improvements in the surface reactivity of the powder particles.

There are a number of areas still available for research, and there is no doubt that there will be further improvements in the near future. Both the powder and the liquid remain open to variation, and there is always the possibility of the use of dispersed-phase inclusions to lead to reinforcement. Alternative polyalkenoic acids have already been tried, and there are still others available. It should be possible to vary both the reactivity and the wetability of the powder; and the actual composition of the glass is open to endless variation. It is suggested that future improvements will probably arise within the auto cure system rather than through resin modification. The risk now is that such measures may downgrade the acid–base setting reaction, the ion-exchange mechanism and the fluoride release, which are the real strengths

Figure 5.26

There is a large occlusal lesion on a lower second molar. Mild symptoms over the last few days have been reported, so it was decided to place an interim restoration to give the pulp the chance to overcome an apparent inflammation.

Figure 5.27

The enamel has been cut back sufficiently to allow access to the infected dentine. The walls around the full circumference have been cleaned to allow ion-exchange adhesion with the dentine and enamel, and the cavity will now be conditioned. Note that there remains a reasonable quantity of affected demineralized dentine on the floor.

Figure 5.28

A fast-set high-strength glass-ionomer has been syringed into the cavity, and the tip of a gloved finger will be used as a matrix to apply positive pressure and ensure full adaptation of the cement.

Figure 5.29

The completed transitional restoration. This will remain in place for at least three weeks to allow the pulp to recover; but it may not be replaced for some months until the caries index has been reduced.

Figure 5.30

This patient presented with an extremely high caries index. It was decided that it was not possible to control the disease until all cavities had been temporarily restored.

Figure 5.31

The two buccal lesions on the bicuspids have been cleaned around the full circumference, but the affected demineralized dentine on the axial wall remains undisturbed.

Figure 5.32

An auto cure high-strength glass-ionomer has been syringed into each cavity, and these transitional restorations will remain in place until the disease is under control.

Figure 5.33

Six months later the patient seemed to have stabilized, so more aesthetic Type II.1 glass-ionomers were substituted. The affected dentine on the floor of both cavities appeared to be entirely remineralized.

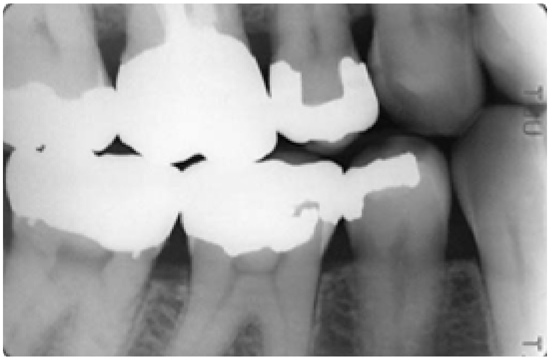


Figure 5.34

A bitewing radiograph reveals a small lesion on the distal of the upper-left canine, which requires restoration.

Figure 5.35

A very conservative tunnel cavity has been prepared to give access to the infected dentine.

Figure 5.36

In this position aesthetics is of no concern, so the strongest available Type II.2 auto cure glass-ionomer material was used.

Figure 5.37

A subsequent radiograph shows the extent and radiopacity of the restoration.

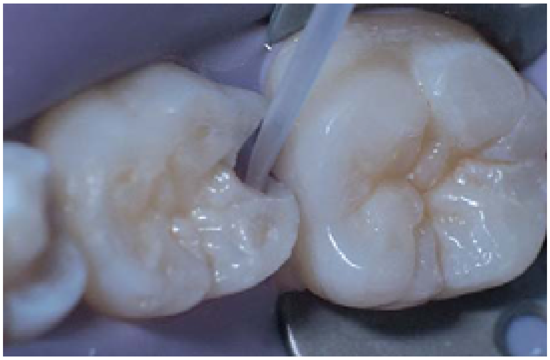


Figure 5.38

There is a reasonably extensive slot cavity in the distal of the lower second deciduous molar, and this will be restored with the strongest auto cure glass-ionomer.

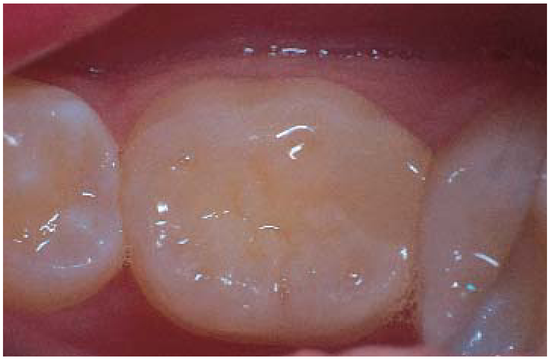


Figure 5.39

The completed restoration photographed 2 years after placement.

Figure 5.40

Shortly after the last photograph the tooth was shed and returned to the operator for a careful examination.

Figure 5.41

The tooth has been sectioned mesio-distally through the restoration. Note the remineralized dentine on the axial wall of the proximal box.

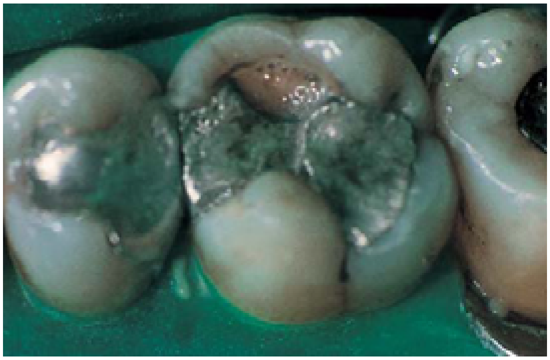


Figure 5.42

There is a large amalgam restoration in this tooth, and it has failed along the buccal margin. It was apparent that there was active caries below the margin, and the patient had reported mild symptoms over recent times.

Figure 5.43

The amalgam has been removed, revealing extensive highly active caries, probably closely related to the mesiobuccal horn of the pulp.

of the glass-ionomers, and must therefore be retained if they are to continue to be bioactive and so useful in modern operative dentistry.

Clinical experience over a reasonably long-term is the only measure through which a new material can be judged, and the original auto cure glass-ionomers have proved adequate for all situations that are not subject to undue occlusal load. The next stage will require materials with a fracture resistance similar to amalgam while still retaining the essential systems associated with the present generation. The following factors apply equally to all the materials mentioned above.

Significant factors

Powder–liquid ratio

In most clinical situations optimum physical properties will be required when utilizing these materials; so the powder–liquid ratio is important. The higher the powder content, the greater the strength, but the more difficult they are to mix by hand. The standard ratio ranges between 3:1 and 4:1, and all the current variations are available in capsules as well as for handmixing. There is a serious temptation to reduce the powder content when handmixing; but this is very undesirable, because of the reduction in physical properties. It is strongly recommended that the materials should be used in a capsulated form to obtain optimum physical properties and results.

Time to mature

These are all relatively fast-setting materials (some are very fast-setting) and will therefore be resistant to water loss and water uptake as soon as they are set sufficiently to be resistant to indentation by a sharp instrument. A protective seal will not be required as long as the restoration remains in a wet environment; and

it appears that they may even be stronger if they are exposed to water early after the initial set (Leirskar et al, in press). However, they will need protection from dehydration if they are to be exposed to air for longer than a few minutes.

Contouring and polishing should always be carried out under air/water spray at intermediate high speed using fine polishing diamonds. Note that the materials remain subject to dehydration for approximately 2 weeks after placement. Therefore if a newly placed restoration is to be left exposed for any length of time or re-exposed within the next 2 weeks, it should be covered and protected with a layer of low-viscosity, single-component, light-activated resin–enamel bond to maintain the water balance.

Adhesion to enamel and dentine

The new high-strength materials undergo the usual acid–base setting reaction so that there will be free polyacrylic acid available at the interface with the tooth when first placed. This means that the ion-exchange adhesion will be identical to the original auto cure materials; but the adhesion will be stronger because the cement is stronger. Failure will be cohesive in the cement itself rather than adhesive at the interface. This means that, as usual, the cavity should be conditioned with 10% poly(acrylic acid) for 10–15 seconds to remove the smear layer and enhance the potential for the ion-exchange layer to ensure optimum retention.

Release of fluoride and other ions

Ion release is similar to that for all other types of auto cure glass-ionomers. This makes the material particularly suitable for restoring such lesions as root-surface caries and tunnels, where cavity outline is often difficult to determine and remineralization of surrounding tooth structure is important.

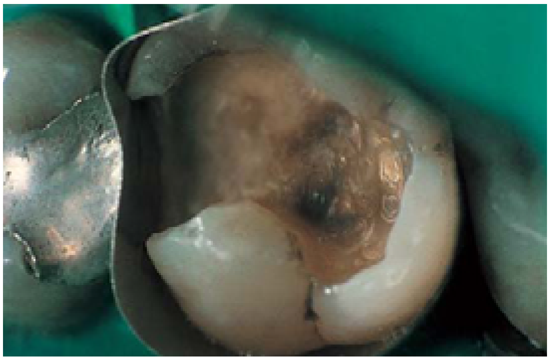


Figure 5.44

The surface infected dentine has been cautiously debrided and care has been taken not to progress as far as exposing the pulp. Note particularly that the margins of the lesion have been completely debrided down to sound dentine, so that there will be complete adhesion between the glass-ionomer and the tooth.

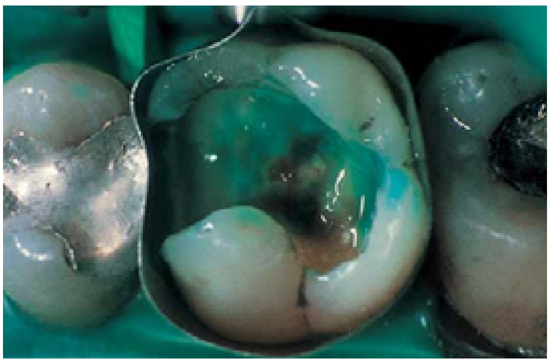


Figure 5.45

The cavity is now conditioned with 10% polyacrylic acid for 10 seconds, washed and dried but not dehydrated.

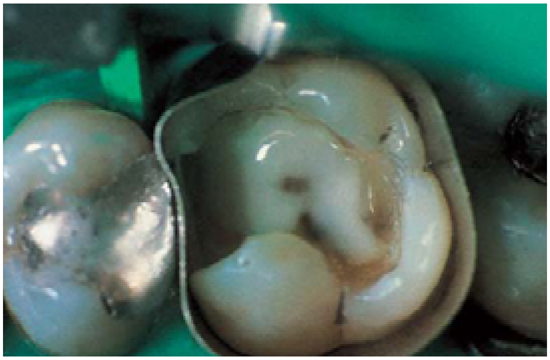


Figure 5.46

The floor of the cavity has now been covered with a thin layer of a low powder–liquid ratio glass-ionomer in the expectation that there will be some element of ion-exchange with the demineralized affected dentine remaining on the floor.

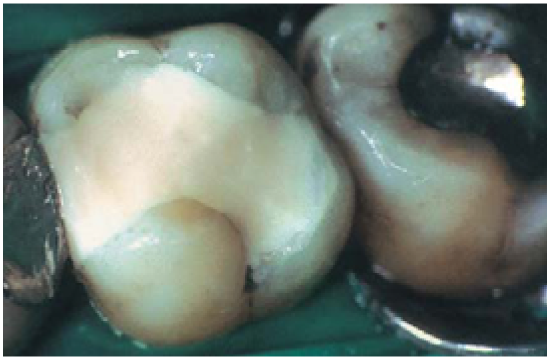


Figure 5.47

The cavity has now been restored entirely with a high-strength, auto cure glass-ionomer and kept under observation for one year. At this time the restoration is still intact, and a decision has to be taken as to whether to laminate this with a more permanent material.

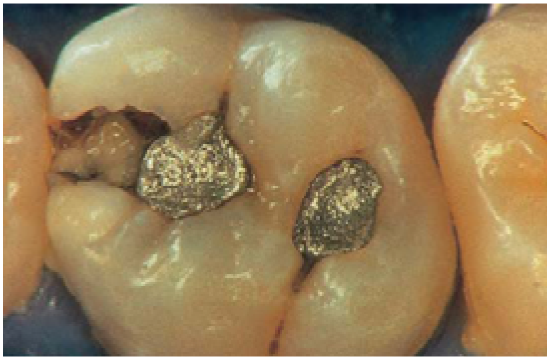


Figure 5.48

This patient presented with a difficult proximal lesion complicated by the presence of an old occlusal restoration that had been poorly placed and showed marginal leakage. The patient reported mild symptoms only over a brief period.

Figure 5.49

Most of the enamel from the buccal cusp was lost during cavity preparation, so the finished cavity design was very extensive. Note that the entire margin has been cleaned down to sound dentine, but the axial wall is still in softened demineralized affected dentine. This will be retained, because to remove it would almost certainly lead to a pulp exposure.

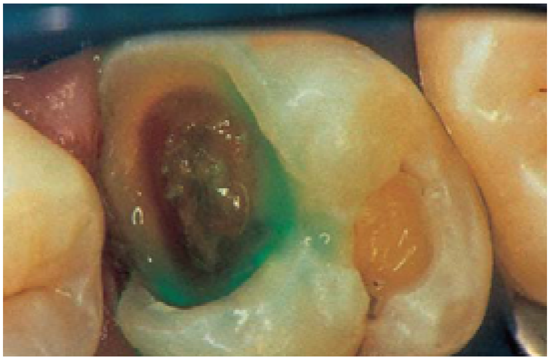


Figure 5.50

The completed cavity is now being conditioned with 10% polyacrylic acid for 10 seconds only. Note that the enamel transverse ridge has been retained, because to remove it would weaken the tooth crown, and an occlusal dovetail design is not required when using adhesive restorative materials.

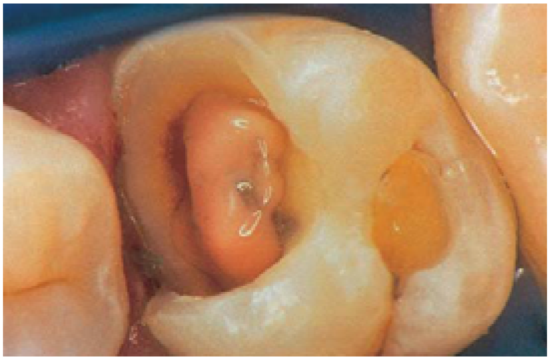


Figure 5.51

Following conditioning a small quantity of a light-initiated auto cure glass-ionomer is flowed over the axial wall and light-initiated to achieve a rapid set. The advantage of this ‘sub-lining’ is that it is relatively strongly antibacterial, and this is a desirable feature in this position.

Figure 5.52

A high-strength auto cure glass-ionomer is now laid down over the sub-lining and allowed to cure. It is then cut back to expose the enamel walls, so that the remainder of the cavity can be restored with composite resin. Another advantage of the light-initiated glass-ionomer is that it is easily detected below the overlay of stronger glass-ionomer while one is trimming the base ready for the laminate. The entire cavity is now being covered with a thin layer of a glass-ionomer bond.

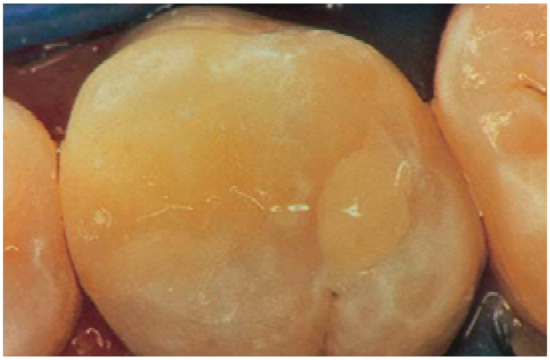


Figure 5.53

The completed restoration following an incremental build-up with composite resin. Note that the distal fissure will remain restored with a high-strength auto cure glass-ionomer only.

Pulp compatibility

As has been discussed previously (page 51), there is only a short-term inflammatory response in the pulp tissue from a newly placed glass-ionomer (Snuggs et al, 1993). In the presence of the ion-exchange with dentine and enamel, there can be no microleakage leading to bacterial invasion, so that the introduction of bacterial toxins and other by-products is thus prevented. It is suggested, therefore, that there is no need to place a sub-lining first. For the same reason, it is only necessary to remove the infected surface dentine from a carious lesion, leaving behind the softened, demineralized, affected dentine, removal of which may lead to an exposure of the pulp. In the presence of the ion-releasing glass-ionomer, the remaining dentine will remineralize and the tooth will have a good chance of retaining its vitality (Figures 5.44–5.53).

Physical properties

Both the tensile strength and fracture resistance of the new generation of these materials are substantially greater than those of the early auto cure materials, and they are marginally superior to those of the resin-modified glass-ionomers. As they mature they match up with both amalgam and composite resin in abrasion resistance. This comes about as a result of the continuing ion-exchange, which leads to surface enrichment with both calcium and phosphate ions as these ions replace the fluoride ions that are lost into the saliva. Radiopacity is adequate for easy identification, because most of them contain a strontium or lanthanum glass rather than the original calcium glass. It seems that there are two areas that can be regarded as their main application. First, they are suitable for minimal lesions that are well supported by surrounding tooth structure but may be subject to occlusal load. And second, they are very useful as a transitional restoration in large lesions where it is deemed desirable to seal a lesion to allow it to heal before selecting the final restoration. If aesthetics is a problem under any circumstances it is always possible to laminate the restoration with a composite resin.

6 Type III: Lining and base materials

Description

As was discussed earlier, this group can be divided into lining cements and base cements, and this latter category could be more accurately described as a dentine substitute. As a dentine substitute the glass-ionomer becomes an integral part of the lamination or 'sandwich' technique, and this is now accepted as the preferred method of bonding composite resin to dentine.

The only difference between a lining and a base is the powder–liquid ratio, and for either application it is acceptable to use either an auto cure or a resin-modified material. One of the earliest uses of the original glass-ionomers was as a lining under a metallic restoration, on the assumption that it was necessary to line a cavity to interrupt temperature change. It has now been shown that it is possible to use a glass-ionomer bonding material (see Chapter 3) to achieve the same result. However, with the composite resins, it is apparent that a simple low powder–liquid ratio lining will not be strong enough to withstand the setting shrinkage, so that the concept of a higher-strength base was evolved. While the two concepts use the same material, there is a considerable difference in the physical requirements of each.

Definition

Lining

A lining can be defined as a thin layer of a neutral material placed on the floor of a cavity, prior to final restoration, to make good a deficiency in the cavity design or to provide thermal protection to the pulp (Figures 6.2–6.9). A lining should not be expected to have any direct therapeutic effect on pulp tissue, unless the pulp is exposed.

Base

A base is identified as a dentine substitute that is placed to make up for major areas of dentine loss

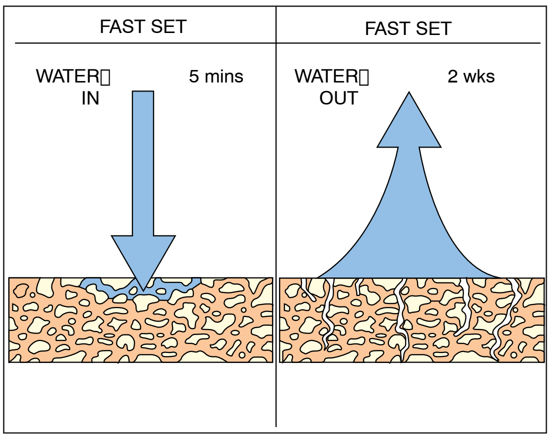


Figure 6.1

Diagram showing the water balance of the auto cure Type III glass-ionomer materials. As they are fast-setting, they are resistant to water uptake in about 5 minutes from the start of mix. This means they can be etched shortly after removing the matrix. However, if they are left exposed to air for any length of time, they are liable to lose water and crack.

Glass-ionomer as a lining under amalgam

Figure 6.2

An extensive amalgam restoration is about to be placed in this cavity. It would be desirable to place a lining first to prevent temperature transmission through the metallic restoration, and the lining can be either a calcium hydroxide or a glass-ionomer.

Figure 6.3

A glass-ionomer is preferred as the lining, because it is stronger than calcium hydroxide, will adhere through an ion-exchange mechanism, and will release calcium, phosphate and fluoride ions, thus encouraging remineralization of underlying dentine.

Figure 6.4

Note the limited amount of glass-ionomer placed. It is no more that 0.5 mm thick and covers the area of the pulp only.

Figure 6.5

The finished amalgam restoration. Provided the occlusion is correct the patient will not have problems with temperature fluctuations.

Figure 6.6

A large cavity in a lower molar has been lined with a thin layer of glass-ionomer prior to placement of an amalgam restoration. Note that it is primarily the pulpal roof that has been covered.

Figure 6.7

Another example of a glass-ionomer lining prior to the placement of an amalgam restoration. Note the limited covering of the floor of the cavity. Note that, as adhesion of such a lining is of no significance, there is no need to condition the cavity first, although there will be no harm done by conditioning.

Figure 6.8

A cross-section through a molar tooth that had been restored with amalgam some years ago. Note the thin section of the lining. There is no need for the lining to be any thicker than that.

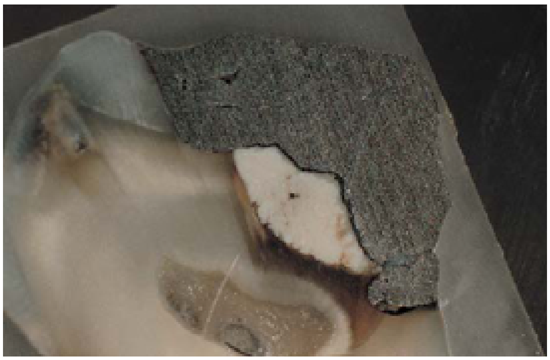


Figure 6.9

A cross-section through an unsatisfactory amalgam restoration showing a very thick zinc oxide and eugenol lining. Note that the restoration received no support from this, and it may have contributed to failure of the restoration and the loss of the tooth.

prior to the lamination of an enamel substitute over the top. It is useful under a difficult and extensive amalgam (Figures 6.10–6.17) and is also a very valuable method of bonding composite resin to dentine (Figures 6.18–6.25). Auto cure or resin-modified materials can be used for either application, and the modern high-strength, auto cure glass-ionomers are, at present, the material of choice.

The concept of a base goes back to GV Black, who suggested that there was a need to 'base out' a deep cavity so that the cavity design could be refined to the 'ideal' geometric shape before the placement of amalgam. Linings were developed later, on the understanding that there would be some therapeutic effect upon the pulp tissue to compensate for the trauma initiated by active caries followed by the additional damage to the pulp arising from preparation of the cavity. These theories sometimes even dictated removal of sound dentine to make room for the lining. Many complex techniques have been described, and apparent benefits to the health of the pulp have been claimed. However, recent work has shown clearly that the pulp has far greater powers of recovery than were ever suspected, and that a therapeutic effect from a lining material, through sound dentine, does not exist (Hume & Massey 1990). The presence of bacteria – in particular, future invasions of bacteria under a newly placed restoration – is far more deleterious to the pulp, and can lead, through continuing inflammation, to post-insertion sensitivity and to pulp death (Brannstrom, 1982). In fact, if a healthy, uninfected pulp is mechanically exposed, it is only necessary to seal it from bacterial invasion and it will heal (Cox & Suzuki 1994).

The purpose of placing a traditional lining, then, is threefold:

- When restoring a tooth by an indirect technique, it may be desirable to modify a cavity to allow for a simplified line of withdrawal and insertion.
- If the cavity is deep and penetrates more than half-way to the pulp, and a metallic restoration is to be placed, a thin layer (0.5 mm) of a lining material may offer a degree of thermal protection to an inflamed pulp. This will keep the patient comfortable during the period of healing.
- A lining may assist in sealing the restoration against bacterial invasion. There will inevitably be bacteria left behind at the time of restoration, but, provided the cavity is sealed, the bacteria will become dormant and remain inactive. The problem arises when there can be ingress of nutrients and new bacteria from the oral environment. Bacterial activity, resulting in production of toxins, will lead to continuation of any existing pulpal inflammation, and, possibly, to pulp death.

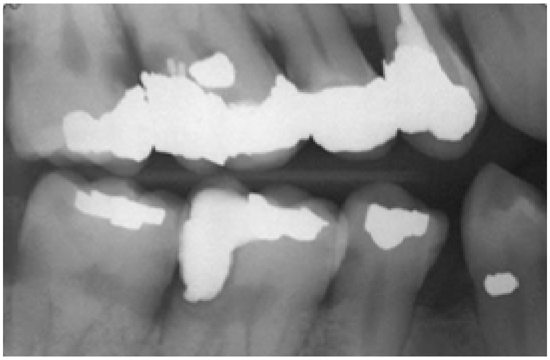
The material that will provide the most effective long-term seal to dentine is glass-ionomer. It is necessary, then, to consider the main restorative materials and determine the best method of obtaining optimum results using glass-ionomer as the primary dentine sealant to prevent microleakage.

Indirect restorations

Placement of a lining in relation to indirect restorations, such as gold or porcelain inlays, is generally a convenience for the development of a line of withdrawal of an impression and the correct insertion of the finished restoration. It will be aimed primarily at reducing the problems of impression taking and the construction of working models. The need for sealing dentine against bacterial invasion may also exist, as well as for thermal protection. The ultimate integrity of the marginal seal will depend on the accuracy of the laboratory techniques used, followed by the use of a luting cement with thermal properties close to those of tooth structure and with low solubility. Glass-ionomer offers all of these properties.

Amalgam

In the past it was considered essential to place a lining under an amalgam restoration for both thermal and therapeutic properties. In fact, it was taught that the cavity should be extended sufficiently to make room for the extra material. It has now been shown that the therapeutic properties are neither available nor necessary, so the need for a lining is confined to those cavities that are already relatively deep and in close proximity



Cermet laminated with amalgam

Figure 6.10

A bitewing radiograph shows the presence of a large cermet restoration in the distal of the lower right first permanent molar that has been poorly placed. There is a rough proximal contour, and caries appears to be still present. Note further carious lesions in the opposing first and second molars and a distal cavity in the lower-right second bicuspid, so that the patient has a high caries index.

Figure 6.11

Cavity design has been completed in the lower first molar. The rubber dam has been lifted mesially to show the condition of the gingival tissue in relation to the gingival margin of the cavity. The tissue tolerance of the original cermet was such that the gingival tissue remained moderately healthy in spite of the poor contour.

Figure 6.12

A standard metal matrix has been placed without a matrix retainer and gently wedged at the gingival to give a degree of support without distortion (see Box F, page 182). The cavity was conditioned with 10% poly(acrylic acid) for 10–15 seconds and then overfilled with a cermet, which was tamped into place with a small plastic sponge. It was allowed to set for 6 minutes before the cavity design was modified.

Figure 6.13

An amalgam-style cavity was prepared in the cermet, under air/water spray at intermediate high speed, to just below the contact area with the adjacent second molar. Normal mechanical interlocks were cut in the remaining tooth structure to retain the amalgam, and a groove cut in the cement to ensure an interlock. A thin layer of cement has been left on the pulpal floor as a normal lining. A very small quantity of 45% poly(acrylic acid) was applied to the cermet on a cotton pledget, and any excess was gently wiped off, so that the amalgam would adhere to the cermet.

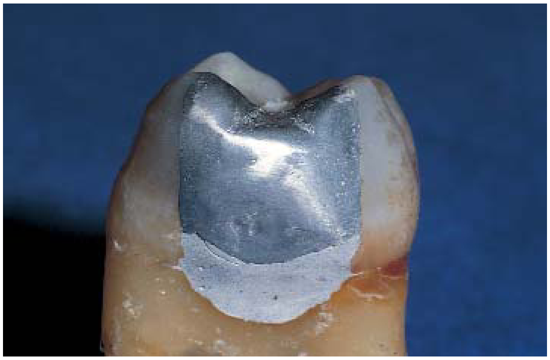


Figure 6.14

A similar restoration has been placed in an extracted tooth to demonstrate the amount of cermet left exposed to the oral environment at the gingival margin. Retention of the cermet in this area provides better contour with less chance of an overhang and a higher tissue tolerance than would amalgam.

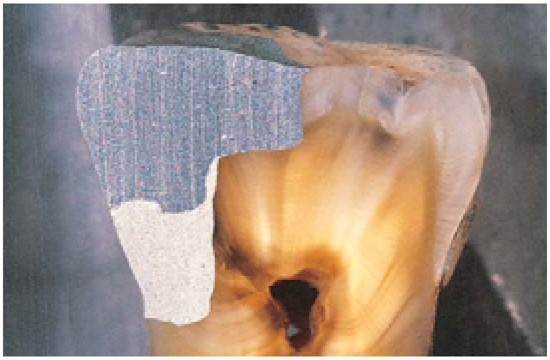


Figure 6.15

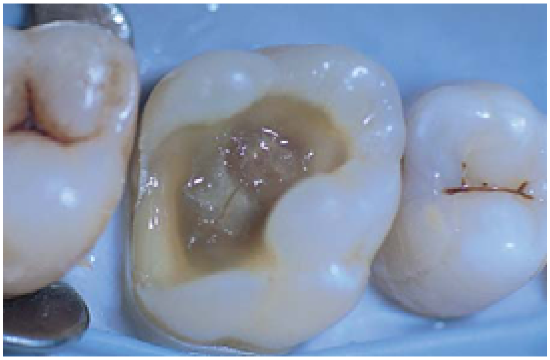
The simulated restoration on the extracted tooth has been sectioned mesio-distally to show the cermet occupying the gingival half of the proximal box. Note that there has been a small amount of mechanical retention provided in the cermet to ensure a mechanical interlock with the amalgam.

Figure 6.16

A normal amalgam matrix was applied and the amalgam condensed as usual. Note the protective cavity design. The tunnel cavity in the second bicuspid was also restored with a cermet at the same appointment. The occlusal of this restoration was subsequently laminated with composite resin.

Figure 6.17

Bitewing radiograph showing the finished restoration in the first molar, as well as the tunnel restoration in the second bicuspid. The upper-right first and second molars have also been restored with amalgam laminated over a cermet in a similar fashion.



Glass-ionomer laminated with composite resin

Figure 6.18

The first step in a series showing placement of a composite resin-laminated restoration in the laboratory. The cavity has been prepared as if in the mouth and is ready for placement of the glass-ionomer base. It will now be conditioned, and a mylar strip will be placed and lightly supported by a wooden wedge.

Figure 6.19

The entire cavity has been restored with a fast-set, high-strength, auto cure glass-ionomer. This will be allowed to set for approximately three minutes after placement, by which time it is ready to be further modified.

Figure 6.20

The glass-ionomer has been cut back to prepare a cavity suitable for a composite resin. The occlusal has been reduced by about 3.0 mm so that there will be sufficient strength in the composite resin to withstand the occlusal load with minimal flexure. Glass-ionomer has been left along the gingival margin, because there is no enamel remaining to which to obtain an etched bond with the composite resin.

Figure 6.21

Both the enamel and the glass-ionomer are now etched with 37% orthophosphoric acid for 15 seconds to ensure a micromechanical union between the composite resin, the glass-ionomer and the tooth.

Figure 6.22

The etched glass-ionomer and enamel are now painted with a thin layer of a bonding resin, the excess is blown off and the bond is light-activated.

Figure 6.23

A short length of mylar strip is placed between the teeth as a matrix and supported with a wooden wedge, which is positively placed between the teeth to open the contact area to some degree. The composite resin can now be built incrementally, beginning at the buccal corner of the distal proximal box.

Figure 6.24

The entire restoration is built incrementally until complete. This view shows the completed restoration from the distal. Note the glass-ionomer exposed along the gingival of the proximal box, where there is a lack of enamel to which to gain attachment for the composite resin.

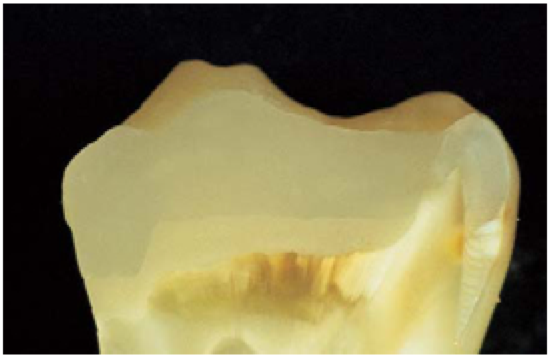


Figure 6.25

The tooth has now been sectioned mesio-distally to show the glass-ionomer base or dentine substitute, with about 3.0 mm of composite resin over it as the main restoration.

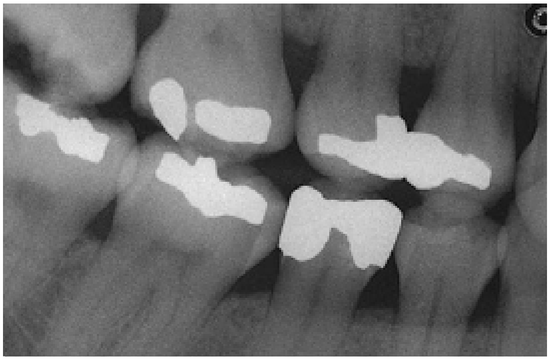


Figure 6.26

This is a clinical case showing the same method for build-up of a laminate restoration. The bitewing radiograph shows a new carious lesion at the mesial of the first molar and an old broken-down amalgam in the second bicuspid.

Figure 6.27

An occlusal view of the two teeth, which require new restorations.

Figure 6.28

The old amalgam has been removed from the bicuspid and the cavity in the molar will now be prepared.

Figure 6.29

Both cavities have been completely restored with glass-ionomer. Both cavities will be modified to accept a composite resin laminate; but the entire proximal of the molar will remain in glass-ionomer. The lesion was not extensive, and a considerable quantity of enamel has been retained because it will be supported with the glass-ionomer.

Figure 6.30

The glass-ionomer has now been cut back to design a cavity suitable for composite resin, and both the remaining tooth structure and the glass-ionomer are being etched for 15 seconds.

Figure 6.31

The bicuspid has now been restored incrementally with composite resin, and the occlusal of the molar has been treated similarly.

Figure 6.32

A photograph of the two restorations taken 5 years after completion.

Figure 6.33

A bitewing radiograph of the restorations taken 8 years following placement. Note that the mesial of the molar is restored entirely in glass-ionomer, with a composite resin overlay on the occlusal only. Note from the radiograph that the mesial of the molar is not under heavy occlusal load.

to the pulp. Removal of additional tooth structure to make room for the lining is strictly contra-indicated. The lining should be placed in thin section, and only where necessary for thermal control, thus leaving room for the amalgam to be placed in bulk and to develop optimum physical properties.

Amalgam shows a unique ability to seal its own margins through corrosion, and the initial placement of copal varnish to control this has been well tested over many years. Even the modern non-gamma 2 alloys will allow sufficient corrosion over time to prevent bacterial invasion. This means that adhesion between the dentine and a lining cement is probably unnecessary. However, it has been shown that fluoride released from a glass-ionomer lining may be available externally through the margin, and may offer a degree of protection against bacterial activity and demineralization.

Therefore, where amalgam is the material of choice, and the cavity is of minimal dimension, no lining need be placed and the corrosion factor can be relied upon to provide a marginal seal. For a cavity that has progressed further than half-way to the pulp a small quantity of glass-ionomer lining material should be placed in the vicinity of the pulp. There is no need for the placement of an additional 'therapeutic' lining such as calcium hydroxide. For convenience and ease of placement a low powder–liquid ratio mix is adequate, because the cement will not be subjected to undue load, and optimum physical properties will therefore not be required. The cement used can be either an auto cure or a resin-modified material; and, mixed at a ratio of 1.5:1, it will flow readily, be easily placed and, if a resin-modified material, or a light-initiated auto cure material is used, it may be set on command.

An alternative situation can arise when a large proximal lesion proves to be extremely deep, and the placement and proper condensation of amalgam poses problems. Under these circumstances, it is possible to use a lamination technique, with a high-strength glass-ionomer restoring the gingival section of the proximal box and the amalgam overlay protecting the glass-ionomer from undue occlusal load. As the glass-ionomer will be exposed to the oral environment and subject to some load, it is essential to use a high powder–liquid ratio material that will develop the best possible physical properties (Figures 6.10–6.17). Provided there is sufficient access for the placement of the activator light, a resin-modified material can be placed, although the new high-strength Type II.2 auto cure materials will generally be the material of choice. The glass-ionomer will now be a definitive part of the final restoration.

Having completed the cavity design, place a short length of either a metal or a mylar matrix strip and support this lightly with a wedge. Condition the cavity and syringe in sufficient of the high-strength glass-ionomer to extend to within 2–3 mm of the contact area. Tamp the cement into place to ensure proper adaptation to the cavity floor and walls. Extend it over the pulpal floor if thermal protection is required. As soon as the cement is set, cut it back and contour it to a final amalgam cavity design, including retentive grooves and ditches to allow for a mechanical interlock between the glass-ionomer, the tooth and the amalgam. Make sure there is sufficient room for the amalgam, because this will be the ultimate restoration, which will accept the full occlusal load and, in many such situations, protect both the glass-ionomer and the remaining tooth structure. At this point it will be possible to develop some degree of chemical union between the cement and the amalgam by applying a light smear of polyacrylic acid over the glass-ionomer and wiping off any excess (Warren & Soderholm 1988). Apply either copal varnish or a glass-ionomer bond over the remaining cavity walls, place and wedge the usual metal matrix band and pack the amalgam.

The resultant laminated restoration has all the advantages of the strength of amalgam, combined with the marginal seal, tissue tolerance and fluoride release of glass-ionomer. It also overcomes the problems of proper condensation, contouring and polishing of amalgam in interproximal regions that are difficult to access. It is a common problem to leave overhangs and overcontours in these areas when restoring with amalgam alone, and this can be a relatively simple answer to this problem.

The same concept can be applied to the design and placement of indirect restorations, although in many instances, if a tooth is badly broken down, it is likely that an extracoronal restoration will be the preferred option. However, there may be occasions where replacement of dentine in such a manner may simplify the design of a gold

or porcelain inlay, leading to the preservation of a significant amount of normal tooth structure.

Composite resin

Long-term adhesion of composite resin to enamel is no problem, and can be achieved through the acid-etch technique pioneered by Buonocore (1955). However, long-term adhesion between composite resin and dentine continues to pose difficulties. The main obstacles appear to be the setting shrinkage of the composite resin and the hydrolytic breakdown of the resin component. The setting shrinkage complicates the situation regardless of the curing mechanism used. Depending on how heavily the resin is filled, shrinkage can vary from 1% to 5% of bulk. When the curing mechanism is chemical, the direction of shrinkage will be towards that area of the restoration that sets first. This will generally be towards the floor of the cavity, where the temperature of the tooth may well be the initiating factor. Certainly the shrinkage will be more inwards and towards the tooth than the reverse. There will be some stress exerted on the bond to dentine, but, since the chemical reaction is relatively slow, the stress will be generated slowly, and there may be some compensation over time.

However, if the composite resin is light-activated, the setting reaction will commence immediately adjacent to the light source, and, depending on the total volume shrinkage expected of a particular composite resin, there may be considerable stress applied to any adhesive mechanism at the tooth–restoration interface. While the total shrinkage can be minimized by building the restoration incrementally, it is not possible, at this point, to eliminate it entirely. Certainly, to some extent light-activation can be applied in such a direction that the resin will shrink towards, rather than away from, the cavity floor and walls; but, while this technique is satisfactory in theory, it is not always possible in practice.

It is also necessary to take into account the vagaries of the dentine in both composition and orientation of the tubules. The deeper the cavity the larger the tubules and the greater the area of cavity floor occupied by the tubules. Whilst the tubules will be vertical to the occlusal floor, they will be horizontal along the gingival floor in the proximal box. The older the patient the denser and more sclerotic the dentine and the poorer the etch pattern. All these factors will have a bearing on the efficiency of the dentine-bonding system employed, and at this time no system is perfect.

The problem, then, is to develop a union between dentine and composite resin that will withstand the stresses of the setting reaction and maintain a sound margin at the interface. It is currently suggested that dentine can be safely etched with various concentrated acids, and the buffering capacity of the dentine can be relied upon to neutralize the pH and protect the pulp. This will then lead to a mechanical interlock into the dentine tubules as well as the development of a hybrid layer similar to that developed with acid-etched enamel. However, the anatomy of the dentine tubules is not necessarily regular and uncomplicated, so etch patterns will be variable. Also, this still does not overcome the problem of dealing with an anhydrous material in the presence of a continuing dentine fluid flow.

Many techniques have been explored to develop a chemical union through bonding agents rather than a mechanical one, and these are becoming increasingly complex and difficult to apply correctly in clinical practice. Evidence suggests that none of these so far remain sound, over time, in the presence of water. On the other hand, the use of glass-ionomer as a bonding mechanism between dentine and composite resin has been extensively explored over recent years, and offers a high level of reliability along with tissue compatibility and long-term release of fluoride and other ions. As a water-based material it will not have the same problems of dealing with the continuing dentine fluid flow.

Lamination requires that the glass-ionomer is used as a base and not as a lining (Figures 6.18–6.33). It is essential to use the strongest material available, and it needs to be in reasonable bulk (McLean et al, 1985; Mount, 1989). The cavity should be conditioned to ensure the development of the usual ion-exchange adhesion between the glass-ionomer and the dentine. Once the cement is set it can be trimmed back to develop an appropriate cavity, with sufficient bulk allowed for the composite resin and all enamel margins exposed to allow for a resin to enamel-bond. The integrity of this union will rely heavily

upon the strength of the enamel, and that will need to be fully mineralized, free of micro-cracks and lightly bevelled to allow union with the ends of the enamel rods rather than along their long sides. A mechanical or chemical union can then be developed between the tooth and the resin, leading to the production of a 'monolithic' reconstruction of the tooth with true adhesion between all three layers – tooth, glass-ionomer and composite resin.

As glass-ionomer is a water-based material, it relies on the continuing presence of water for stability, and the question of hydrolytic breakdown does not arise. However, the setting shrinkage of the composite resin must be understood and taken into account, and this means that only the strongest glass-ionomers can be relied upon to produce and maintain a sound union with dentine. There is no doubt that the bond between sound acid-etched enamel and composite resin is the strongest available, and should be utilized wherever possible. But, if there is no enamel available, or that which remains is weak and friable, a strong glass-ionomer will be adequate as long as it is properly placed and protected from undue occlusal load.

The advantages of this technique include maximum exposure of glass-ionomer to the oral environment for the release of fluoride and other ions and a reduction in the total amount of composite resin commensurate with the required strength in the ultimate restoration. Also, it is desirable to replace the interproximal tooth structure in relation to the gingival tissue with the glass-ionomer because of its resistance to plaque build-up and its high tissue tolerance. While the occlusal load will be dissipated to some degree by the composite resin, it is important that only the strongest possible glass-ionomer should be used, so that it can offer maximum support for the composite resin and will be able to withstand dissolution and erosion interproximally.

Significant factors

Powder–liquid ratio

The physical properties of these lining or base materials depend upon the powder–liquid ratio, so that if high strengths are required in the ultimate base, as in the lamination technique, a high powder–liquid ratio, of at least 3:1, must be used. The higher the powder content, the shorter will be both the mixing time and the working time. While most of the lining cements are marketed for handmixing, the capsulated varieties, which can be machine-mixed, will provide more reliable results with better physical properties, because they are sure to have the correct powder–liquid ratio.

Materials with a low powder–liquid ratio, in the range of 1.5:1, are useful as all-purpose cavity linings, but are not strong enough to be used under composite resin unless there is a margin of sound enamel around the complete circumference of the cavity. In thin section their tensile strength will not be high, but the rapid-setting reaction means early achievement of a compressive strength high enough to withstand the heavy packing pressure used in the placement of amalgam. At this consistency, they are also useful for correcting minor deficiencies when carrying out crown preparation. For correcting major defects, the heavier 3:1 ratio should be used.

Time to mature

All the auto cure cements in the Type III category are designed to be fast-setting and therefore resistant to water uptake within 5 minutes from the start of mix. They should undergo a snap set at that point and be ready for trimming as required and the placement of the final restoration. If several restorations are being placed at the same time, care must be taken to ensure that the cement does not dehydrate, particularly when working under a rubber dam. For the same reason, when they are used as a dentine substitute, all trimming should be undertaken under air/water spray.

Resin-modified glass-ionomers can be used for either application, and the problems of water loss can be avoided. However, proper activation of the cement is necessary, and access for the placement of the light may be a limiting factor. If an extensive build-up is required in a difficult situation, such as a distal proximal box in a molar tooth, then an auto cure material may be required. On the other hand, incremental placement of a resin-modified material may be just as efficient.

Adhesion to enamel, dentine and composite resin

Chemical adhesion is available between the glass-ionomer and the underlying tooth structure, provided that the smear layer and other debris have been removed first by conditioning with 10% poly(acrylic acid) for 10–15 seconds. However, if the material is being used simply as a conventional lining, under an amalgam for example, then this step is unnecessary and can be omitted (Figures 6.2–6.5). If the cement is to be used as a base or dentine substitute under composite resin in the lamination technique, there are two interfaces to be considered (Figure 6.25):

- the union between the glass-ionomer and the dentine
- the union between the glass-ionomer and the composite resin.

With both auto cure and resin-modified material the union with tooth structure will develop through the usual ion-exchange between the two, and will be enhanced by prior conditioning with poly(acrylic acid) (Mount 1991).

The union between the composite resin and the glass-ionomer is either mechanical or chemical. With the auto cure materials it is necessary to etch with 37% orthophosphoric acid for 15 seconds to develop a roughened surface, rather like etched enamel, to ensure a mechanical union between the two. Etching for a longer period of time will only remove further glass-ionomer and will not improve the bond (Fuss et al, 1990). Application of either a thin layer of resin–enamel bond or a glass-ionomer bond will ensure a good union.

After setting, the resin-modified materials still retain a number of unreacted polymer chains, and these are generally sufficient to develop a chemical union between the two materials. Etching is unnecessary, but will do no harm if some acid does get onto the surface. Application of a resin–enamel bond will ensure good adaptation between the two materials. In theory, the technique should work well and provide the optimum ‘monolithic’ restoration. However, there are some limitations, and the following points should be taken into account.

The tensile strength of the glass-ionomer is the weakest link in the chain. Therefore the strongest cement available should always be used, particularly if the restoration is to be subjected to heavy occlusal load. The Type III base glass-ionomers have been developed with this technique in mind, and the Type II.2 materials are also satisfactory. The resin-modified Type II.1 restorative aesthetic materials have high physical properties and acceptable aesthetics, so they can also be used in the laminate technique. In a situation where aesthetics is of primary concern, such as an upper anterior lesion, this will often be the material of choice (Figures 6.34–6.41).

The dentine should be conditioned with a 10–15 second application of 10% poly(acrylic acid) to remove the smear layer and any other contaminants that may be present. This will also preactivate the calcium and phosphate ions in the dentine in preparation for the ion-exchange with the cement (Figure 1.50).

The glass-ionomer must cover all dentine tubules and should never be less than 1 mm thick, and the highest powder–liquid ratio available should be utilized. It can then be left exposed to the oral environment at the gingival margin of the restoration, and so full advantage can be taken of the adhesion to dentine as well as the ion release. A material with a low powder–liquid ratio should not be exposed to the oral environment at the margins of a restoration, because its physical properties are not good enough and its solubility will be relatively high (Figures 6.42–6.57).

Release of fluoride and other ions

The external release of fluoride and other ions is relatively insignificant if the material is to be entirely covered by another restorative, such as amalgam or composite resin. However, there are many circumstances in the lamination technique where the glass-ionomer will be exposed to the oral environment at the gingival margin, underneath the other material. Fluoride release will then be useful for plaque and caries control in both the restored tooth and adjacent ones (Figure 6.24). Also, of course, the potential for stimulating remineralization on the floor of the cavity will always be present and can be most valuable, particularly when dealing with extensive cavities in a patient with a high caries index.

Glass-ionomer as a lining under composite resin

Figure 6.34

This series shows an anterior restoration in which the glass-ionomer is used essentially as a lining only because there is adequate enamel around the entire restoration to allow for an etched enamel adhesion.

Figure 6.35

A lingual view of the cavity being conditioned prior to placement of the glass-ionomer. Note that this is replacement dentistry, so the cavity design is already dictated and is in fact larger than necessary.

Figure 6.36

A base has been placed using a high-strength, resin-modified glass-ionomer essentially as a lining. It covers the dentine only, and leaves the enamel available for an etched bond around the full circumference; and its translucency will not complicate colour matching.

Figure 6.37

The entire enamel margin is etched for 15 seconds with 37% orthophosphoric acid. As a resin-modified glass-ionomer was used in this case there is no need to etch it.

Figure 6.38

A lingual view showing the usual frosted appearance of the enamel following etching.

Figure 6.39

A labial view of the tooth, showing the same frosted appearance of the enamel, which is now ready for bonding.

Figure 6.40

A lingual view of the completed restoration.

Figure 6.41

A labial view of the completed restoration.

Glass-ionomer as a base under composite resin

Figure 6.42

Old amalgam restorations in an upper molar require replacement because there is further caries at the bucco-gingival margin of the proximal box, where the amalgam was not fully condensed.

Figure 6.43

The old restorations have been removed along with the caries, and the cavity is being conditioned prior to placement of the glass-ionomer.

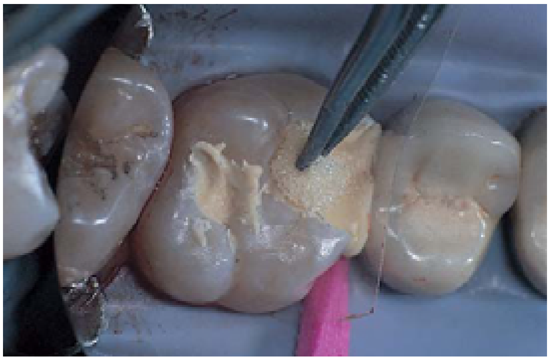


Figure 6.44

A short length of mylar strip has been placed interproximally to act as a matrix and lightly supported with a wedge. A fast-set, high-strength, auto cure glass-ionomer has been syringed into place to act as a base or lining in both cavities, and is allowed to set briefly.

Figure 6.45

The glass-ionomer has now been cut back to develop a cavity design suitable for a composite resin, exposing the entire enamel margin around the circumference. As the enamel at the gingival was sound and well supported by healthy dentine it was lightly bevelled and allowed to remain.

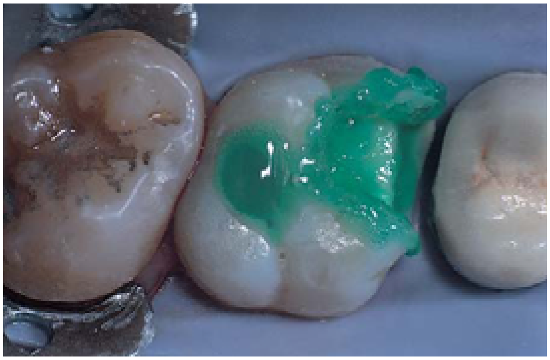


Figure 6.46

The enamel and the glass-ionomer are now etched with 37% orthophosphoric acid for 15 seconds, washed thoroughly and dried lightly. A resin bonding agent is painted over the cavities and light-activated.

Figure 6.47

A short length of mylar strip is placed interproximally and supported well by a light-transmitting wedge in an attempt to open the contact area and ensure a good contact with the adjacent tooth.

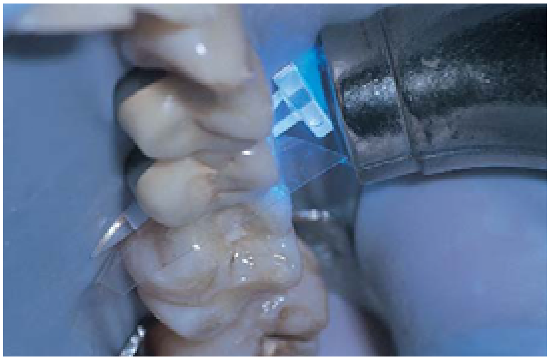


Figure 6.48

The restoration is built incrementally, beginning at the bucco-gingival point angle and light-activating through the wedge. Continue with small increments, light-activating through the tooth where possible.

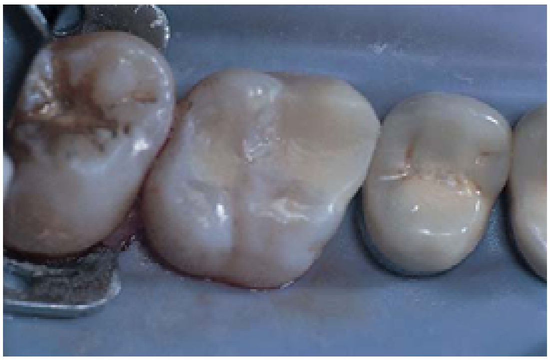


Figure 6.49

The completed restoration at the time of insertion.

Glass-ionomer compared with composite resin

Figure 6.50

Two extensive cervical lesions on the upper-right central and lateral incisors have been restored with an auto cure glass-ionomer. The shade match on the lateral incisor seemed to be less than ideal, so it was decided to laminate it with composite resin.

Figure 6.51

The glass-ionomer was cut back to a depth of approximately 2 mm. Both the glass-ionomer and the enamel were etched for 15 seconds, washed thoroughly and dried lightly.

Figure 6.52

The cavity surface was covered with a light application of a low-viscosity unfilled resin–enamel bond, and composite resin was built incrementally to complete the restoration.

Figure 6.53

The completed restorations photographed 3 years after placement. Note the satisfactory aesthetic result obtained with both glass-ionomer alone (central incisor) and the laminate technique (lateral incisor).

Use of glass-ionomer following trauma

Figure 6.54

Following a motor vehicle accident, this young patient presented for emergency treatment with a Class II fracture of the distal incisal corner of the upper-left central incisor. Dentine was exposed and the tooth was very sensitive. However, the pulp was still covered and apparently vital.

Figure 6.55

The fractured surface was conditioned for 10–15 seconds with 10% poly(acrylic acid), flushed and lightly dried. A Type II.2 restorative cement was syringed over the dentine, without building up the incisal corner. No matrix was used, and just as the cement set it was covered with a very-low-viscosity, light-activated bonding resin to prevent hydration or dehydration. The bond was light-activated, and the patient was immediately comfortable and safe to be maintained under observation.

Figure 6.56

Four weeks later, pulp tests suggested that the tooth had settled down and was unlikely to lose vitality, so it was restored with composite resin. The glass-ionomer was very lightly cut back to a fresh surface, the enamel was bevelled and both glass-ionomer and enamel were etched with 37% orthophosphoric acid for 10–15 seconds. Composite resin was used to build up the corner.

Figure 6.57

The completed restoration photographed at the next recall appointment.

7 Minimal intervention cavity designs: The place of glass-ionomers

In recent times the term 'Minimal Intervention Dentistry' has been coined to describe a new approach to the restoration of carious lesions. It has now been clearly acknowledged that caries is a bacterial disease and that treatment should therefore revolve primarily around overcoming the infection. It will then often be possible to interrupt the process and actually heal the early lesions prior to cavitation of the surface of the crown of the tooth. If this action is too late or unsuccessful, and the enamel surface is damaged sufficiently to retain plaque, then some degree of surgical intervention will become necessary to restore the smooth surface once more. But it is suggested that any surgical intervention should be as minimally invasive as possible and should provide only for the removal of completely demineralized infected tooth structure. Remaining, partially demineralized enamel and dentine should be retained and remineralized wherever possible. This will lead to extensive preservation of natural tooth structure and this, in turn, will minimize aesthetic problems and at least slow down the need for replacement dentistry.

The pattern of attack of the carious lesion and its progress through the enamel and dentine has been understood for many years, and has tended to dictate the treatment methods used (Figure 7.1). However, the purely surgical approach to caries control, as taught by GV Black, is now recognized as being far too destructive to be used

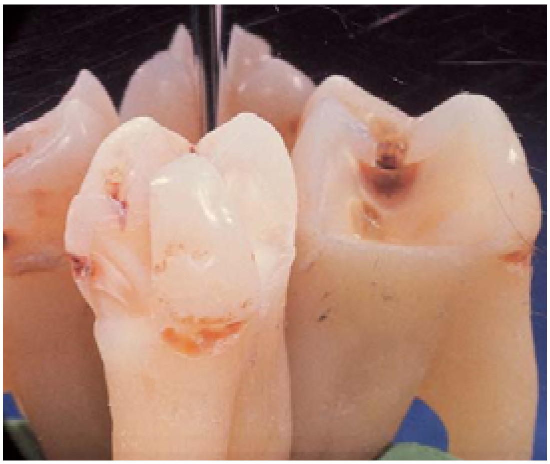


Figure 7.1

An extracted tooth has been sectioned to show three different carious lesions and the direction of penetration of the advancing caries. Note the two stages of the occlusal lesions. On the left the caries has only just penetrated through the fissure and entered the dentine, but on the right the pulp is now almost involved. The penetration by the caries is twice as deep as it is wide, and has followed the direction of the dentinal tubules, with a degree of lateral spread. The proximal lesion on the left has entered the enamel on a narrow front and then progressed inwards and downwards along the path of the dentinal tubules. This pattern of attack for all lesions is significant in the design of cavities that are intended to remove caries only and to minimize the loss of further tooth structure.

as the first line of defence. It is relatively inefficient because it does not cure the disease, and the major problem is that it leads to a continuing process of replacement dentistry wherein the cavity just gets larger and the tooth gets weaker.

Minimal intervention means that there should be greater emphasis upon education and direction of patients towards self-care, with the intention of preventing or healing the disease in the first place and eliminating the need for surgical intervention. It is now recognized that it is quite possible to heal a lesion provided it has not progressed to the stage of surface cavitation. It is not suggested that this approach is any easier than traditional surgery; but it is far more conservative of tooth structure, and offers the possibility of far greater longevity for the dentition in general. It also suggests that there is no longer a need to sacrifice natural tooth structure by the preparation of relatively large cavities on the assumption that this will prevent further disease.

The knowledge required for the adoption of this new philosophy has been accumulating for a number of years, and the principles have been utilized in enough practices to suggest that they are sound. There have been many articles in the scientific literature over the last 20 years suggesting greater emphasis on preventive measures and modified cavity designs, and there are now at least three textbooks (Wilson & McLean 1988; Mount & Hume 1998; Roulet & Degrange 2000) covering the subject in some detail. There is no doubt that the old concept of 'extension for prevention' should at this point be discarded; but it is acknowledged that there is a need for further investigation into the cavity designs proposed to take its place.

It is understood that no restorative material can be regarded as permanent, and that there will, in time, be further breakdown of either tooth structure or restoration. Any restored lesion is at risk of becoming larger, at least to the extent that the remaining tooth structure will be weakened by cavity preparation. With each replacement, the cycle is likely to move faster to the next stage of breakdown and replacement.

Significantly, any alteration to the occlusal anatomy of a tooth, through placement of a restoration, may lead to changes in occlusal harmony. Even a minor change in occlusal anatomy can lead to the introduction of undue stress on remaining cusp inclines, to the development of deflective inclines and to functionally opening contacts – all of which will speed the decline of the occlusion and may lead to periodontal problems as well.

It is logical, therefore, to retain as much of the original tooth crown as possible in the first place and deal with a lesion in need of repair in a very conservative manner. None of the simple plastic restorative materials can be regarded as ideal or permanent; but at the same time each of them carries some advantage for limited circumstances. Amalgam is the old original plastic restorative; but it is not in the least aesthetic, and it requires removal of a considerable amount of tooth structure simply to have room to condense it properly and to develop mechanical retention. Composite resin has a growing record of success for relatively minor lesions, but works best in the presence of a sound enamel margin around the full circumference of the lesion. It is highly aesthetic, but it is a bland material with no inbuilt ability to protect its own margins in case of microleakage. Glass-ionomer is aesthetic and biologically active (see Chapter 2), but is relatively brittle and will sometimes need to be laminated to protect it from heavy occlusal load.

This chapter will discuss the varied uses of glass-ionomer in the application of minimal intervention principles in operative dentistry. While it is not suggested that it should be regarded as universal, it does provide the opportunity for introducing a modified cavity design for the treatment of the initial lesion, and this in turn may lead to conservation of a considerable amount of remaining unaffected tooth structure. Such minimal cavity designs should be regarded as a first stage prior to the more conventional designs that may still be required later in the possible downward disintegration of tooth structure if the disease should recur or be allowed to continue.

The advantages of the glass-ionomers for restoration of minimal lesions can be listed as follows:

- minimal removal of sound tooth structure required for access to the lesion;
- this will allow minimal alteration to occlusal and proximal tooth anatomy;
- glass-ionomer flows freely and is simple to place in confined areas;
- the ion-exchange adhesion prevents microleakage;
- the ion-exchange adhesion will unite with and reinforce remaining enamel and dentine, and restore physical strength;

- continuing ion release enhances caries resistance and encourages remineralization;
- glass-ionomer appears to remain biologically active throughout its life; and
- acceptable aesthetics can be readily obtained.

The greatest value lies in the restoration of minimal new lesions so that its biological activities can be used to the maximum and it will not be exposed to undue occlusal load. The relatively low fracture strength may be regarded as a limitation but wear resistance improves considerably as it matures. This means that as long as it is well surrounded by sound tooth structure it can be placed on the occlusal surface with safety. However, if the proposed restoration is to be heavily loaded then the lamination techniques discussed in Chapter 6 will need to be utilized.

New classification

The concept of minimal intervention cavity designs is not difficult to accept and visualize when contrasted with the traditional GV Black classification. After all, the latter is a classification of *cavities*, wherein the cavity design is specified for each lesion in the expectation that amalgam will be the primary material of choice for restoration. It is suggested that, if minimal intervention is to be adopted as a philosophy, there is a need for an entirely new classification that will identify *lesions* rather than cavities. After all, it is neither necessary nor desirable to specify any particular design for the cavity that may have to be prepared. In the first place it is desirable to identify a lesion before it becomes cavitated, so that it can be subjected to treatment by remineralization and subsequently kept under observation until healed. Following loss of surface integrity and cavitation there will be a need for surgical intervention. The surgical intervention should then be designed simply to eliminate surface cavitation and to ensure that the restoration can properly seal the margins against any potential microleakage.

There has always been a problem with the GV Black classification because it identifies a lesion regardless of size and prescribes the required cavity design. It also fails to take into account the size of the lesion and the potential complexity of the required restorative procedures. This problem of the growing cavity is taken into account with the proposed new approach, to the advantage of both the patient and the profession. The following classification was first proposed in an article in *Quintessence International* in 1997 and subsequently enlarged upon in a textbook (Mount & Hume 1998) and then modified in other articles and a Letter to the Editor (*Quint. Int* 2000; **31**: 375). It is repeated here so that the subsequent discussion on possible variations in cavity design will be better understood.

Table 7.1 shows a diagrammatic representation of the proposed classification, and the following

Table 7.1

SITE \ SIZE	No cavity 0	Minimal 1	Moderate 2	Enlarged 3	Extensive 4
Pit/Fissure 1	1.0	1.1	1.2	1.3	1.4
Contact area 2	2.0	2.1	2.2	2.3	2.4
Cervical 3	3.0	3.1	3.2	3.3	3.4

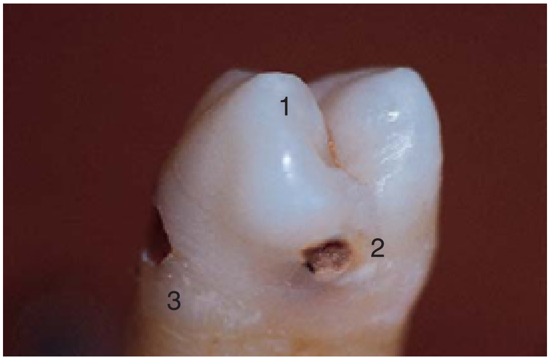


Figure 7.2

The crown of an extracted tooth, showing the three areas that are subject to caries attack. These are the pits and fissures on otherwise smooth surfaces of the enamel crown, the contact areas of all teeth, posteriors and anteriors, and the cervical regions of the tooth, including the exposed root surface. Based on this, a new classification for carious lesions is proposed in Table 7.1.

is an explanation of the number system that is used:

Lesion site

Carious lesions occur in only three different sites on the surface of the crown of a tooth (Figure 7.2).

Site 1 – the pits and fissures on the occlusal surface of posterior teeth and other defects on otherwise smooth enamel surfaces.
Site 2 – the contact areas between any pair of teeth, anteriors or posteriors.
Site 3 – the cervical areas related to the gingival tissues, including exposed root surfaces.

Lesion size

A neglected lesion will continue to extend as an area of demineralization in relation to one of the Sites noted above. As it extends, so the complexities of restoration will increase. The sizes that can be readily identified are as follows:

1. Size 0 – the initial lesion at any Site that can be identified but has not yet resulted in surface cavitation – it may be possible to heal it.
2. Size 1 – the smallest minimal lesion requiring operative intervention. The cavity is just beyond healing through remineralization.
3. Size 2 – a moderate-sized cavity. There is still sufficient sound tooth structure to maintain the integrity of the remaining crown and accept the occlusal load.
4. Size 3 – the cavity needs to be modified and enlarged to provide some protection for the remaining crown from the occlusal load. There is already a split at the base of a cusp or, if the cusp is not protected, a split is likely to develop.
5. Size 4 – the cavity is now extensive, following loss of a cusp from a posterior tooth or an incisal edge from an anterior.

The Site 1, Size 0 lesion represents the occlusal fissure on a newly erupted tooth or similar defects on an otherwise smooth surface that are not yet carious but deserve some discussion in this context. By the time the lesion reaches Size 1 some form of restoration is mandatory, because these lesions (fissures) will be under constant occlusal load, and it is difficult to keep them plaque-free. The Site 2, Size 0 and the Site 3, Size 0 lesions will generally not require restoration; but every effort should be undertaken to heal them through patient education and remineralization. This latter group will not be discussed in any depth in this context, but the reader is referred to one of the more definitive texts on the subject (Mount & Hume 1998).

The Size 1 and Size 2 lesions at all three Sites are the ones that are more relevant and will be discussed in some detail here. Once the lesion reaches the Size 3 category, or beyond, the preferred restorative techniques will involve the use of another material laminated over

glass-ionomer, and the 'lamination technique' is fully discussed in Chapter 6.

Site 1 lesions

Site 1, Size 0

The concept of the fissure seal, as discussed by Simonsen & Stallard (1978), Simonsen (1991) and others, is particularly sound in a newly erupted tooth (Figures 7.3 to 7.6). Sealing a deep fissure before it becomes partially occluded by plaque and pellicle, and in advance of demineralization into dentine, has an acceptable clinical history (Ekstrand et al, 1998). The earliest fissure sealants were unfilled or lightly filled resins; but recent research has shown that there are some doubts about the integrity of the acid-etch union between resin and enamel in these regions. It has been shown that a glass-ionomer will also successfully occlude such a fissure (McLean & Wilson 1977d) and this is now being termed 'fissure protection' to differentiate it from a resin seal.

The anatomy of the enamel within a fissure is different from that of other surfaces, in as much as it is covered with a layer of amorphous enamel crystals that appear to run parallel with the surface rather than at right angles to it (Figures 7.7–7.9). This means that when it is etched with orthophosphoric acid it will not develop the usual pattern of porous enamel that allows penetration of the unfilled resin and that is normally relied upon to provide the micromechanical attachment. The presence of this type of enamel may well account for the loss of the resin in many cases. It must also be noted that neither a resin nor a glass-ionomer will flow into a fissure beyond the point where the fissure narrows down to approximately 200 μ in width (Figures 7.10, 7.11). Therefore retention of both materials depends upon adhesion to the enamel at the entrance to the fissure rather than mechanical interlocking into the complexities of the fissure. Recent work suggests that, even though the enamel rods lie in an orientation different from normal, glass-ionomer will still develop the usual ion-exchange adhesion (Figure 7.12), and will therefore show acceptable longevity.

There have been a number of articles in recent years that show that, in spite of apparent early loss of the low-powder-content glass-ionomer fissure protection, the caries rate in teeth that have been protected with this material remains very low indeed (Smales et al, 1997). It is postulated that this comes about either through retention of traces of glass-ionomer in the depths of the fissure or else because of the fluoride uptake into the enamel prior to the loss of the seal. Other surveys have recorded acceptable longevity for similar restorations using stronger materials, and in these cases the glass-ionomer appears to remain in place very satisfactorily (Figures 7.13, 7.14).

It is suggested that fissure protection with a high strength glass-ionomer should be undertaken as soon as a molar tooth becomes accessible, particularly in the presence of a high caries risk (Feigal 1998). For the young patient who may not be completely amenable to dental treatment, this is a relatively simple task when using a fast-set auto cure material such as the light-initiated auto cure glass-ionomer (Figures 7.15 to 7.18) (Smales et al, 1997).

Site 1, Size 1

As the fissure walls become demineralized the dentine will become involved as well. This may pose a rather dangerous situation, because there is often some difficulty in diagnosing the presence of a dentine lesion. The first response within the dentine appears to be a degree of defensive remineralization of the lateral canals of the dentine tubules, which may only show up as the translucent zone (Thylstrup and Fejerskov 1986) (Figures 7.19 to 7.21). Radiographs will then not show this early lesion; and laser detector and electrical impedance machines have limitations. As this surface is under constant heavy load from mastication it is important that the potential for rapid advance of a lesion is understood. Bacteria-laden plaque can be forced down into a restricted fissure opening and develop considerable hydraulic pressure within the dentine. In the presence of strong, fluoridated enamel the entry to the lesion will remain limited, and release of the pressure will therefore be slow. Under these circumstances dentine involvement can become

Figure 7.3

An occlusal view of an extracted bicuspid, showing some involvement with the fissures. The extent of the involvement is difficult to determine, but it is very unwise to probe the fissure, because this will cause a degree of damage that will then need to be recognized as a cavity and extended and restored.

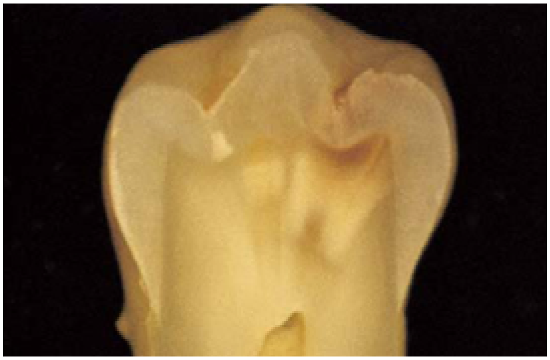


Figure 7.4

The tooth shown in Figure 7.3 has been sectioned, and this reveals the full extent of the caries. Note that the mesial fissure (right side) is deeply involved with active infected caries some distance into the dentine. Simply sealing this fissure would probably arrest the caries, and, as long as the seal was effective, it would not progress. On the other hand, in the presence of a high caries index, the operator may choose to restore it. The distal fissure would be readily stabilized by a glass-ionomer fissure protection.

Figure 7.5

A bicuspid tooth shows some degree of involvement of the occlusal fissures. It will be sectioned mesio-distally to show the complexity of the fissure system.

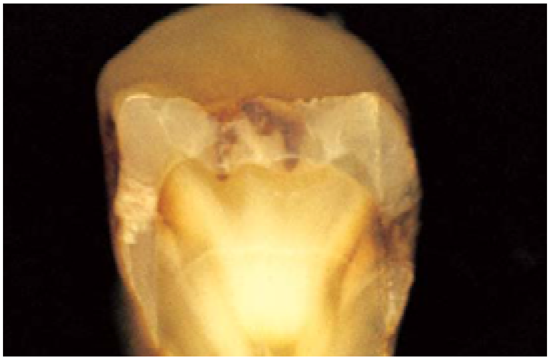


Figure 7.6

The sectioned tooth, showing the fissure system. The main interest here is the convoluted design of the fissures, which vary from a shallow groove across the central portion to deep pits at either end. Even though the pit at the left-hand end does not appear to be through the enamel, it is apparent that the dentine is already involved, because of the presence of a translucent zone, representing some degree of mineralization, arising from the pulp. Note the same type of translucent zones related to the two proximal lesions.

Site 1, Size 0

Figure 7.7

A scanning electron micrograph of the occlusal fissure of a molar, showing a small quantity of plaque trapped within the depths as well as the amorphous layer of enamel down the sides of the fissure.

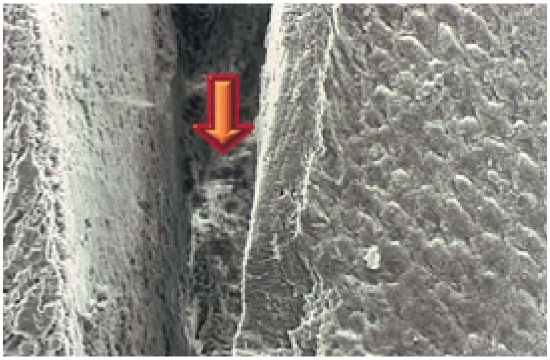


Figure 7.8

A higher-power view of the same tooth. Note the trapped debris as well as the amorphous layer of enamel.

Figure 7.9

A very high magnification of the amorphous layer of enamel. Note that whatever enamel rods there are appear to be running parallel to the surface rather than at right angles to it. This suggests that it will not be possible to develop the usual etch pattern of the enamel surface for micromechanical attachment of a resin fissure seal.

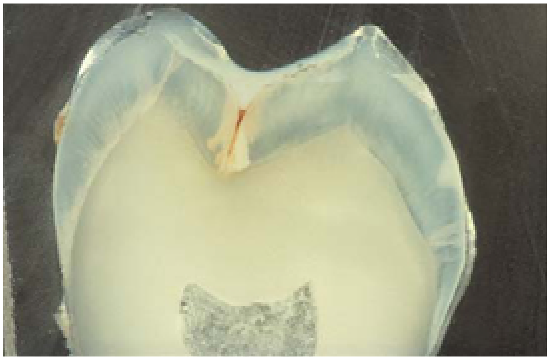


Figure 7.10

A cross-section of a lower molar tooth that has been treated with a resin fissure seal in vitro. Note that the resin has not been able to penetrate to the full depth of the fissure, so that there is some degree of doubt about the micromechanical attachment of the resin into the fissure.

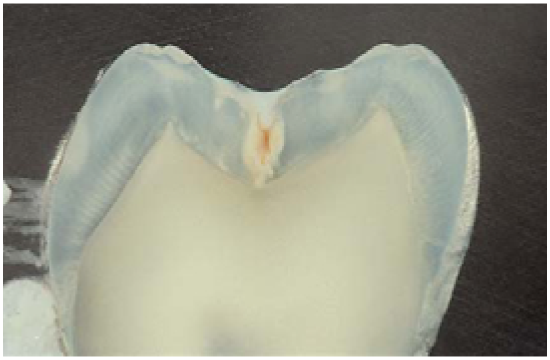


Figure 7.11

A cross-section of a lower molar tooth that has been treated with a glass-ionomer fissure protection. Note that the cement has not been able to penetrate far at all down into the fissure. However, the ion-exchange adhesion will be effective over all the available enamel.

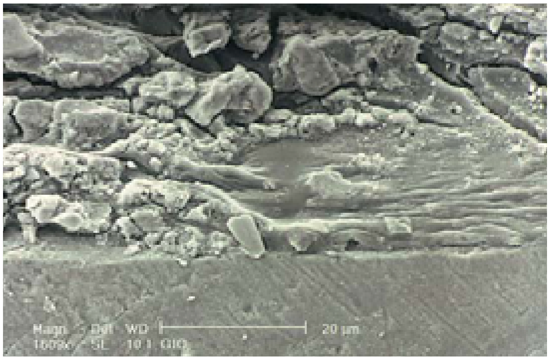


Figure 7.12

A scanning electron micrograph of a glass-ionomer fissure seal demonstrating the usual ion-exchange adhesion to the walls of a fissure some little distance down from the occlusal surface. The glass-ionomer appears to be well attached, regardless of the nature of the enamel rods. Magnification $\times 1600$.

Figure 7.13

A glass-ionomer fissure protection still in place 8 years after placement. At that time the Type II.1 restorative aesthetic glass-ionomer was the most appropriate material available; but the longevity suggests that the material continues to mature in the oral environment.

Figure 7.14

Another example of a fissure protection restoration of advanced maturity. This one is 12 years old, but shows some sign of wear and loss of bulk. However, it is still performing its proper function.

Site 1, Size 0

Figure 7.15

A technique case showing the application of a glass-ionomer fissure protection to an upper second molar to deal with a Site 1, Size 0 lesion. Access is difficult and aesthetics is of no concern. Therefore a light-initiated auto cure material will be used.

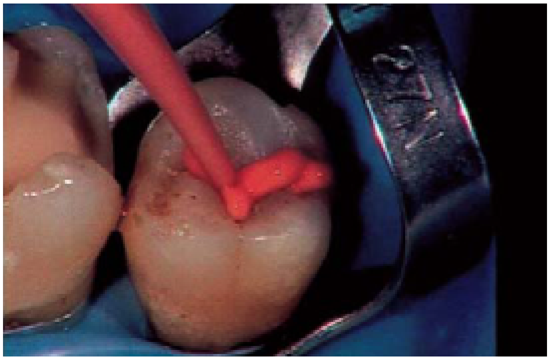


Figure 7.16

The occlusal surface of the tooth has been conditioned and washed thoroughly, and the light-initiated auto cure glass-ionomer is being syringed into place using a disposable syringe.

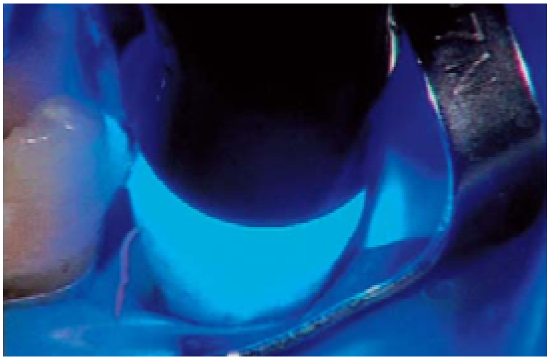


Figure 7.17

The glass-ionomer has been tamped into the fissures and the setting mechanism is now being initiated by the usual activator light. Exposed for 20 seconds to the light, the cement will now be resistant to water contamination and ready to contour.

Figure 7.18

The finished restoration. Note the light-red colour, which is acceptable in areas where aesthetics is of no concern or where this material has been used as a lining and is to be covered by another restoration.

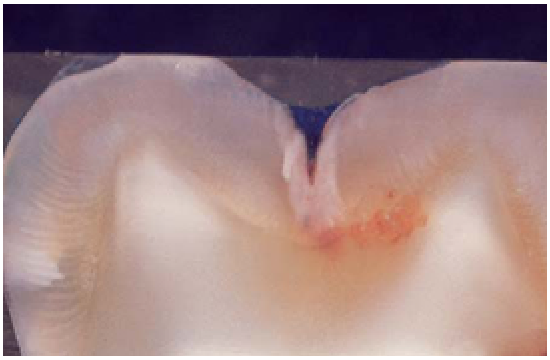


Figure 7.19

A lower molar sectioned bucco-lingually, showing the demineralization of the walls of a fissure, followed immediately by penetration downwards and laterally into the dentine. Beyond the demineralized dentine there is the translucent layer, which represents dentine tubules that have been mineralized to some degree as part of the defence reaction from the pulp.

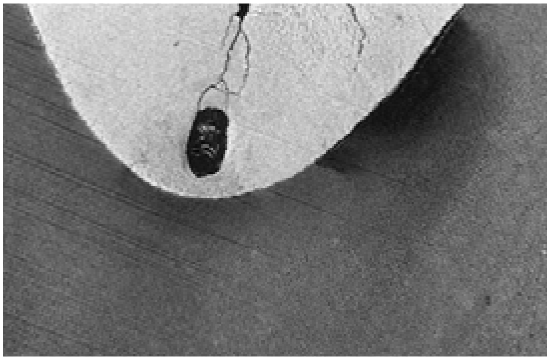


Figure 7.20

A scanning electron micrograph of a similar lesion to that shown in Figure 7.19. Note the translucent tract beyond the enamel, representing the more heavily mineralized dentine generated as a defence reaction by the pulp.

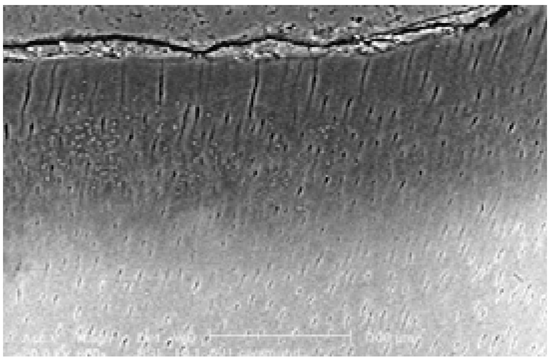


Figure 7.21

The mineralized translucent tract in the dentine at higher magnification. Note that it is the lateral canals in which the additional mineral is precipitated, so that the relative lack of canals renders the dentine more translucent.

extreme long before symptoms are noted (Figures 7.22, 7.23).

The fissure system is invariably a series of pits and fissures, so a carious defect will often be limited to a very restricted area, leaving the remaining fissure system sound and uninvolved. This means that only the carious defect needs to be instrumented. However, prudence may suggest that minor apparent defects should be explored in a very conservative manner before sealing the entire system (Figures 7.24 to 7.34).

Requirements for preparation and restoration

Instruments required (see Box D, page 180)

- Very fine diamond point (#8107 and #3107), at 40 000 revs/min under air/water spray, to open into the carious lesion, and to follow out the fissures as required
- Small round burs, sizes 008–016, for caries removal

Site 1, Size 1

Figure 7.22

An occlusal view of a lower bicuspid that demonstrates clearly the extent to which occlusal caries can progress without overt signs or symptoms. This patient reported pain in only the last two days, and a radiograph showed the extent of the problem.

Figure 7.23

For a variety of reasons the tooth was extracted. It could then be sectioned to demonstrate the fissure, still in its original form, but demineralized down the walls. Penetration into the dentine had then progressed all the way to the pulp chamber in an apparently short time.

Preparation

- Use very fine tapered diamond bur at intermediate high speed under air/water spray to explore the fissures and determine the extent of the problem.
- Remove remaining infected dentine with small round burs at slow speed under air/water spray.
- Use binocular loupes, and good illumination. Do not advance pulpally any further than essential, but develop clean dentine walls around the entire periphery.
- Condition the cavity as prescribed.
- Restore with a high-strength Type II.2 glass-ionomer for preference, because of its superior physical properties and radiopacity. A resin-modified material is satisfactory, but its setting characteristics and water uptake must be taken into account.
- Place the glass-ionomer with a syringe to ensure positive placement into the narrow

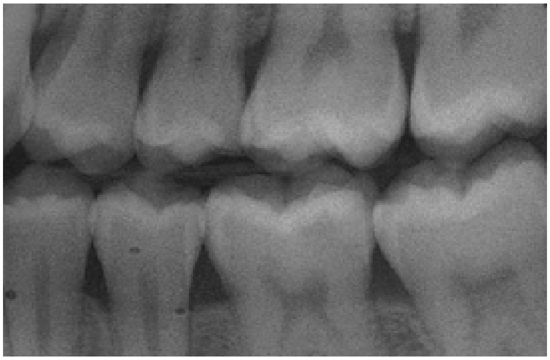


Figure 7.24

A radiograph of this lower first molar shows early signs of caries activity, and the patient has recently developed a high caries index.

Figure 7.25

The clinical view of the situation, showing a small discrete section of the distal fissures involved with caries. The remaining fissures appear to be sound, but they will be protected at the same time as restoring the lesion.

Figure 7.26

The completed cavity design, showing the limited extent of the occlusal involvement. The small pocket of demineralized, infected dentine below was removed, and the walls were cleaned ready for the ion-exchange adhesion.

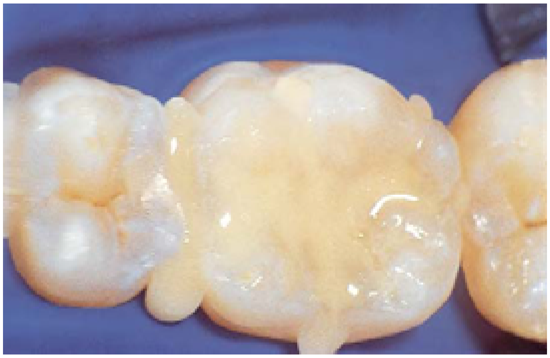


Figure 7.27

The restoration was completed with a high-strength auto cure Type II.2 glass-ionomer. The tip of a gloved finger was used as a matrix to make sure the cement was properly adapted, and this shows the restoration immediately after it was set. The excess was removed from around the crown, and it was sealed immediately to stabilize the water balance.

Figure 7.28

The same restoration photographed three years after placement. The result is entirely aesthetic and satisfactory.

Figure 7.29

A laboratory case showing a Site 1, Size 1 lesion on a lower second molar. The fissures are obviously faulty, and will need to be explored to a limited degree prior to restoration.

Figure 7.30

The fissures have been explored very conservatively using the small tapered diamond bur #8107 at intermediate high speed under air/water spray and then lightly polished using bur #3107.

Figure 7.31

The prepared cavity is being conditioned with 10% polyacrylic acid for 10 seconds only. It will then be washed and dried lightly.

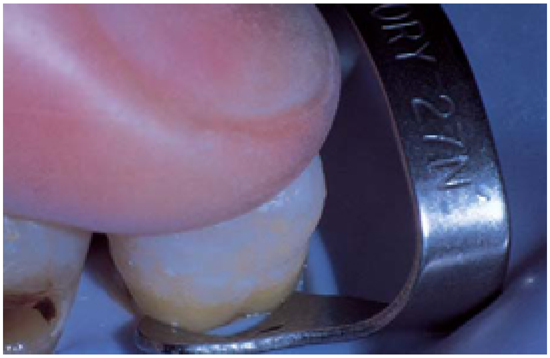


Figure 7.32

A high-strength, fast-set, auto cure glass-ionomer has been syringed into the cavity and it is being pushed to place using the tip of a gloved finger, which has been lightly vaselined to allow easy separation from the set cement.

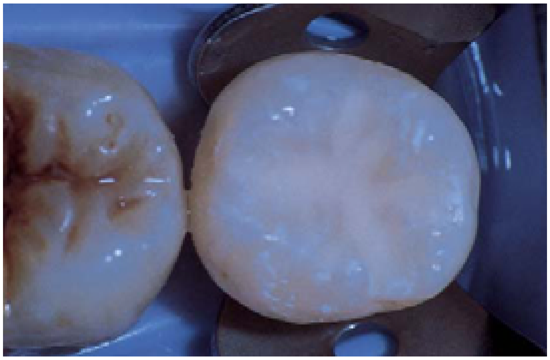


Figure 7.33

The completed restoration following removal of the excess cement. It will now only be necessary to check the occlusion after removal of the rubber dam.

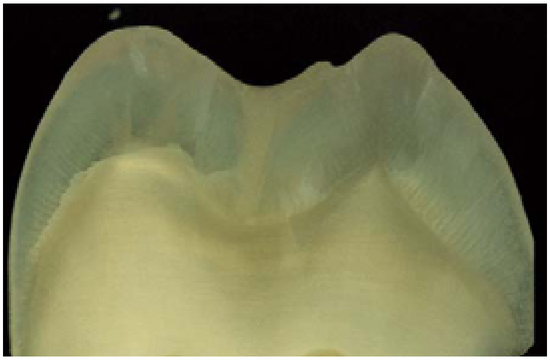


Figure 7.34

As this case was carried out in vitro it was possible to section the tooth subsequently to check the penetration of the glass-ionomer to the depth of the prepared fissure. Note the satisfactory adaptation to the entire fissure; and the enamel has not been fully penetrated.

fissures. When using an auto cure cement, use an occlusal matrix or the tip of a gloved finger as a matrix to apply positive pressure. Hold in place for approximately 1.5 minutes to allow cement to set.

Site 1, Size 2

In this classification either the lesion will have progressed to some degree, or it may represent replacement of a failed GV Black Class I restoration. Accurate diagnosis of a new lesion may be difficult, because of the potential for extensive spread of the dentine lesion under strong fluoridated enamel. The same conservative principles should apply, as discussed above, inasmuch as it is only necessary to deal with the carious lesion, and there is no need to open up the remaining fissures any further. If there is any part of the fissure system in doubt it can be explored very

conservatively; but there is no doubt it is sufficient to seal the fissures, and any carious process below will be arrested. It will progress no further until such time as there is again access to the usual nutrients required by the bacteria. That is, if there is any marginal leakage there will be further activity; but this is very unlikely when using glass-ionomer.

Instrumentation and restoration techniques for these lesions will be the same as for a Size 1 lesion. However, the occlusal involvement will be more extensive, and if there is any doubt about the ability of the glass-ionomer to withstand the occlusal load, it can be cut back conservatively and laminated with composite resin (Figures 7.35 to 7.40).

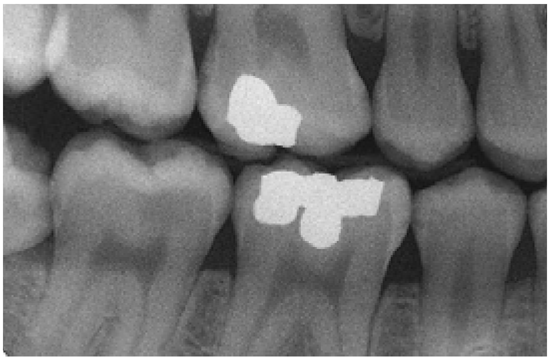
Requirements for preparation and restoration

Instruments required (see Box D, page 180)

- Very fine tapered diamond point (#8107), to explore the fissures as required
- Small tapered diamond bur (#8206) at intermediate high speed (40 000 revs/min) under air/water spray, to gain full access to the carious lesion
- Small round burs, sizes 008–016, for caries removal

Preparation

- Use very fine tapered diamond bur at intermediate high speed under air/water spray to explore the fissures and determine the extent of the problem.
- Use small tapered diamond to gain full access to carious areas.
- Remove remaining infected dentine with hand excavators or small round burs at slow speed under air/water spray.
- Use binocular loupes and good illumination. Do not advance pulpally any further than essential, but develop clean dentine walls around the entire periphery.
- Condition the cavity as prescribed.
- Restore with a high-strength auto cure Type II.2 glass-ionomer for preference, because of



Site 1, Size 2

Figure 7.35

A bitewing radiograph showing a relatively large lesion at the mesial end of the occlusal surface of a lower second molar. This will be classed as a Site 1, Size 2 lesion.

Figure 7.36

An occlusal view of the same lesion, showing the apparently limited area of the fissure system that is involved. The rest of the fissures appear to be free of demineralization, but probably should be explored.

Figure 7.37

The completed cavity photographed at the time of conditioning in preparation for restoration. Note that the remaining fissures have been very conservatively explored to make sure there were no other pockets of caries.

Figure 7.38

The entire cavity was restored with a high-strength, auto cure glass-ionomer, but it was observed that the opposing palatal cusp of the upper second molar engaged the central fossa of this restoration. It was therefore decided to laminate the glass-ionomer with composite resin, because it was expected that this would better support the occlusion. The glass-ionomer has been cut back in the central fossa to a depth of about 2.0 mm.

Figure 7.39

The glass-ionomer and the enamel were etched for 15 seconds, and the composite resin was built incrementally to restore full anatomy. Compare this result with the adjacent first molar, which was restored with amalgam many years ago.

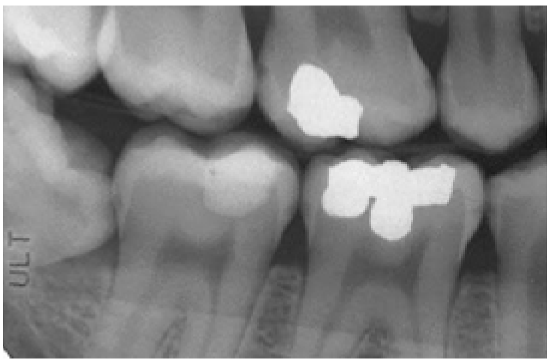


Figure 7.40

A bitewing radiograph taken two years later shows the completed restoration. Note the slight difference in radiopacity between the composite resin and the glass-ionomer.

the superior physical properties and radio-pacity. A resin-modified material is satisfactory, but the setting characteristics and water uptake must be taken into account.
- Place the cement with a syringe to ensure positive placement into the narrow fissures. When using an auto cure glass-ionomer, use an occlusal matrix or the tip of a gloved finger as a matrix to apply positive pressure. Hold in place for approximately 2 minutes to allow cement to set.
- If there is doubt about the ability of the glass-ionomer to withstand the occlusal load cut back to a depth of 2.0 to 3.0 mm, bevel the enamel, etch both enamel and the glass-ionomer and laminate with composite resin.

Site 2 lesions

The Site 2 lesion will develop in relation to the contact areas between any two teeth, anterior or posterior, and will pose a variety of problems if it is to be conservatively prepared and restored. The Size 0 lesion needs to be identified and recorded, and vigorous efforts should be made to try to heal the lesion and prevent progress. There is no doubt that loss of the interproximal marginal ridge will break the integrity of the ring of enamel that surrounds the crown, leading to isolation of the individual cusps. If the medially facing cuspal inclines then remain under direct occlusal load they will eventually become subject to a split at the base, and ultimately the cusp may be lost. This emphasizes the importance of preventing progress of the lesion, if possible; but if these measures fail then a restorative technique that preserves the marginal ridge should be the first choice. Alternative cavity designs will be discussed below; but every effort should be undertaken to avoid cavity preparation in the first place.

It should be noted that radiographic evidence of demineralization at the contact area does not necessarily mean that there is cavitation on the proximal surface, and in the absence of cavitation it is often possible to heal the lesion (Figures 7.41 to 7.44). In fact, proximal lesions progress very slowly, because that surface is not under occlusal load, and is, to a degree, protected from traumatic damage (Pitts 1983; Shwartz et al, 1984). In contrast to the occlusal fissure lesion, it may take up to four years to penetrate the full thickness of the enamel, and a further four years to progress through the dentine to the pulp.

Site 2, Size 0

It is desirable then to be able to differentiate between the Size 0 and the Size 1 lesion, because, at least theoretically, it should be possible to heal the Size 0, and it is only when cavitation is established that a surgical technique is required. It is essential to avoid the use of a probe to explore the proximal surface, because this is the quickest way actually to damage the enamel and cause a cavity. Radiographs can be very misleading, and should not be relied upon. The best way to view the surface is, if possible, to develop a small degree of separation between the teeth, using an orthodontic rubber separating ring, and then to take a rubber base impression of the adjacent surfaces (Figures 7.45 to 7.52). This will reveal, quite accurately, the presence or absence of cavitation. If the surface is still smooth then it is suggested that it should be cleaned and a concentrated fluoride should be applied for a short period. The surface can then be etched and sealed with a very-low-viscosity resin bonding agent. The enamel will be quite porous because of the demineralization; but if it is sealed with the resin it is likely to remain stable for long periods, if not permanently.

Site 2, Size 1

Once it has been established that there is cavitation on the proximal surface a surgical approach to its repair becomes essential, and there are various alternative methods available. First determine the position of the damage in relation to the crest of the marginal ridge. If it is more than 2.5 mm below the crest then it may be possible to approach the lesion through the occlusal fossa and design a 'tunnel' cavity (Wilson & McLean 1988; Hunt 1990; Hasselrot 1998). By contrast, if it is less than this distance, a tunnel will only undermine the marginal ridge and weaken it still

Site 2 lesions

Figure 7.41

In considering proximal lesions – known as Site 2 lesions in the new classification – it is necessary to decide whether the proximal surface is cavitated or not. Early lesions, which may show on bitewing radiographs, are not necessarily cavitated, and if they are not then often they can be remineralized and healed rather than restored. This is a view of the proximal surface of a molar with an area of demineralization in the contact area.

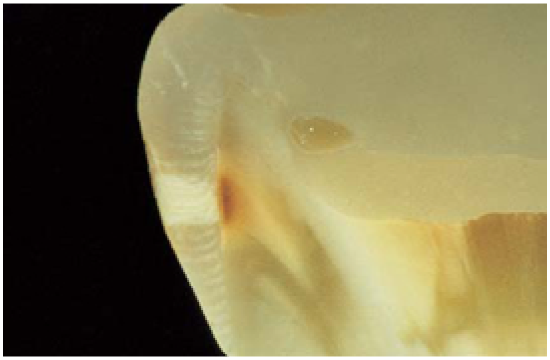


Figure 7.42

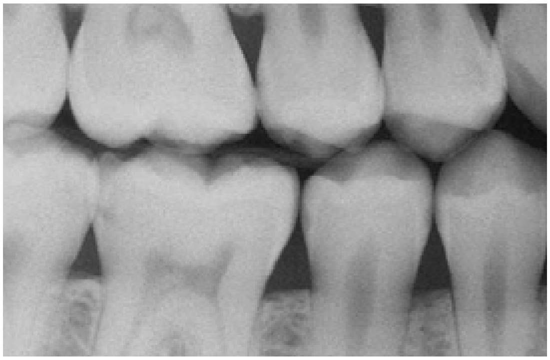
The tooth shown in the preceding illustration has been sectioned, revealing the lesion, which has progressed into the dentine. However, there is no surface cavitation, and therefore there is a possibility of remineralization without restoration.

Figure 7.43

A situation similar to that demonstrated in the previous illustration, but this time there is distinct cavitation on the enamel surface. Restoration for this is mandatory.

Figure 7.44

The tooth shown in the preceding illustration has been sectioned to show the extent of the lesion. Because of the surface cavitation placement of a restoration is essential.



Site 2, Size 0

Figure 7.45

There is a small initial lesion at the distal of the lower first molar showing in the radiograph. The problem is to decide whether it requires restoration or can it be healed. The presence or absence of surface cavitation will be the deciding factor.

Figure 7.46

To gain access to the interproximal space place a standard orthodontic separating rubber band and leave it in place for 48 hours.

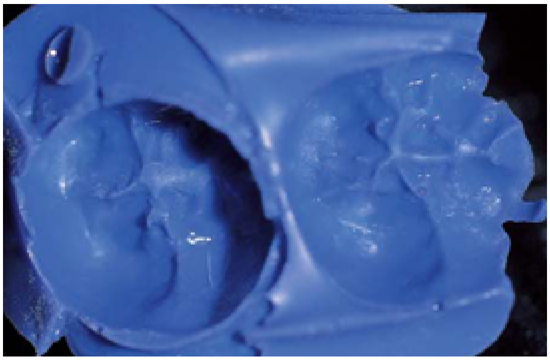


Figure 7.47

Remove the rubber spacer, and if necessary place a wooden wedge to maintain the space temporarily. Wash the area well, and syringe in a small quantity of a rubber base impression material. When it has set remove it and examine it carefully for signs of cavitation on the proximal surface of the tooth in question. This photograph shows that the surface is quite smooth, so it is probable that the lesion can be healed.

Figure 7.48

A similar rubber base impression taken for another patient, which clearly shows the presence of a cavity that will require surgical intervention.

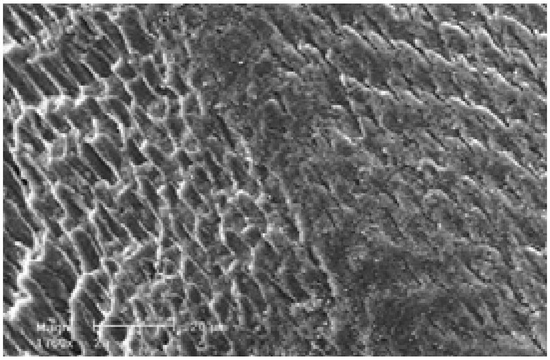


Figure 7.49

A scanning electron micrograph of the enamel on the proximal surface of a tooth that has been demineralized in the early stages of caries. Note that the degree of porosity is sufficient to allow transport of further acid through the enamel, but not of bacteria. Sealing of this surface would be desirable.

Figure 7.50

The teeth shown in Figure 7.45 have been placed under rubber dam to allow better control of the etching process, and 37% orthophosphoric acid has been applied to a limited area. It will remain in place for 15 seconds, and then be thoroughly washed and dried.

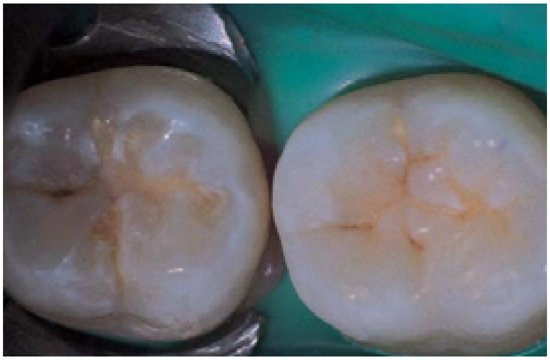


Figure 7.51

The etched areas after drying, showing the normal matt surface on the enamel, signifying a completed etch.

Figure 7.52

The etched surfaces were then painted with a concentrated fluoride varnish and allowed to stand for 5 minutes. The varnish was then washed off and a low-viscosity resin–enamel bond was flowed over the surfaces; the excess was blown off, and the resin was light-activated. The surfaces are now regarded as sealed against further acid attack.

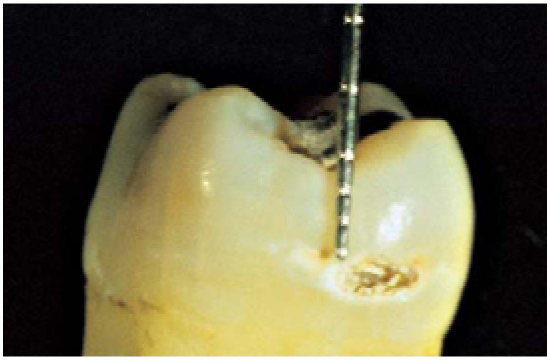


Figure 7.53

There is a lesion on the proximal surface of this molar, and, as is demonstrated by the periodontal probe, it is about 3.0 mm below the crest of the marginal ridge. Under these circumstances it will be possible to repair this lesion through a 'tunnel' cavity design.

Figure 7.54

A proximal lesion on an extracted tooth is less than 2.0 mm from the crest of the marginal ridge. This lesion should be restored using a 'slot' cavity design.

further (Figures 7.53, 7.54). Under these circumstances it is better to design a small box or 'slot' cavity beginning on the outer slope of the ridge and retaining as much of the enamel as possible. Occasionally a further alternative will present itself, when a large Site 2, Size 3 or 4 lesion is being repaired, and a small Size 1 lesion is revealed on the side of the adjacent tooth. These three alternatives will now be discussed in more detail:

Site 2, Size 1 – 'tunnel'

As was discussed above, the early proximal lesion on a posterior tooth will commence in the enamel immediately below the contact area, because this is where plaque will accumulate and mature. Initially, the contact itself will remain plaque-free because of movement between the teeth. The level and depth of fluoroapatite already in the enamel will probably control the speed at which the enamel will actually undergo demineralization. Often, particularly in fluoridated communities, the enamel, although demineralized, will remain relatively intact until the dentine lesion is quite advanced. It will take up stain and become disfigured; but in the presence of further fluoride it may remineralize and become harder than the original enamel. Under these circumstances, it is unnecessary, and, in fact, undesirable, to remove this area of enamel, because removal will separate and weaken the cusps (Papa & Wilson 1992).

As the lesion develops, some degree of breakdown and cavitation of the enamel will eventually occur; but this will remain confined to the area below the contact until it is quite advanced. There will generally be a zone of demineralized enamel surrounding the cavitation; but this remains capable of remineralization in the presence of fluoride. The contact area may remain sound and the marginal ridge may be quite strong provided the lesion is more than 2.5 mm below the crest of the marginal ridge. Access to the lesion through the occlusal surface (Figures 7.55 to 7.62) should be limited to the extent required to

Site 2, Size 1 Tunnel

Figure 7.55

There is a lesion on the proximal surface of this molar that is at least 3.0 mm from the crest of the marginal ridge and will therefore be restored with a tunnel cavity. Initial entry is achieved with a small tapered diamond bur (#8206) at intermediate high speed under air/water spray. Aim the bur at an angle towards the lesion, and proceed until the lesion is identified.

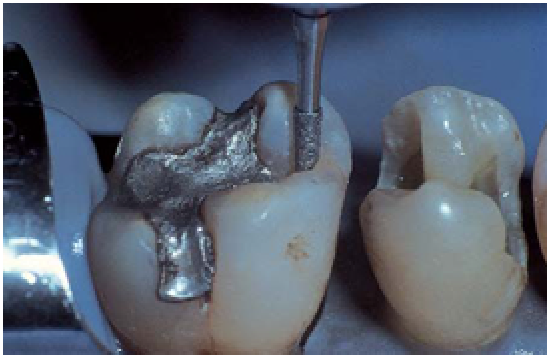


Figure 7.56

Once the lesion is sighted upright the same bur and move gently into the marginal ridge to improve access to the lesion. Lean the bur to the buccal and the lingual to develop a triangular access cavity, and this will expose the full extent of the lesion.

Figure 7.57

An occlusal view to show the extent of the triangular entry to the lesion. As far as possible retain the strength and integrity of the marginal ridge.

Figure 7.58

If there is actual proximal cavitation through the enamel lightly clean the enamel margins without extending the cavity any further than essential. The cavity can now be conditioned, washed thoroughly and dried lightly ready for placement of the glass-ionomer.

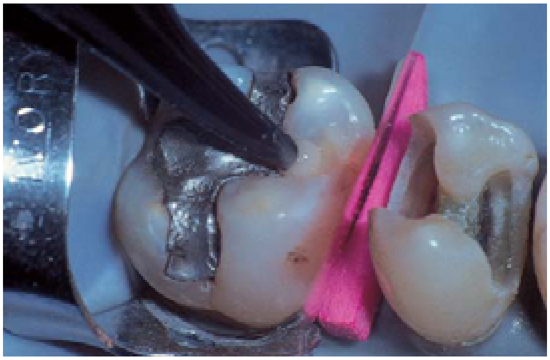


Figure 7.59

The glass-ionomer is syringed to place using a short length of mylar strip as a matrix.

Figure 7.60

A high-strength, auto cure glass-ionomer is placed, and this shows the completed restoration from the occlusal.

Figure 7.61

As this was a technique case it is possible to see the proximal view and consider the extent of the restoration. Note that there is still demineralized enamel around the circumference of the proximal cavity. In the presence of the glass-ionomer it is expected that this will remineralize, provided that the disease has been controlled.

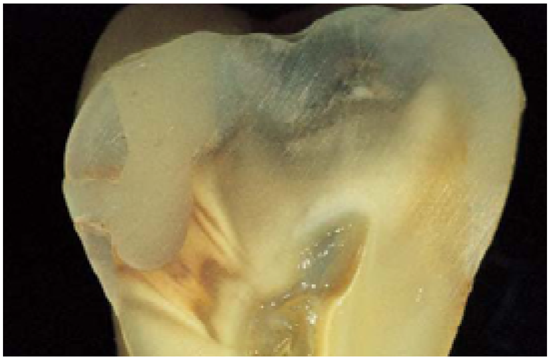


Figure 7.62

The tooth has now been sectioned to show the internal dimensions of the cavity. Note the extent of the demineralization around the circumference of the external lesion in the enamel, which can be expected to remineralize.

achieve visibility, and, where possible, should be undertaken from an area that is not under direct occlusal load (Knight 1984; Hunt 1990). For most patients there is a fossa immediately medial to the marginal ridge, which is the most suitable position for initial entry and, in a normal occlusion, is often not an area of occlusal contact. An examination of study models will be useful in determining the preferred position for access. Following conservative preparation and then restoration with an adhesive cement it has been shown that the strength of the crown will return to a point close to normal (Hood et al, 1981) (Figures 7.63 to 7.81).

Instruments required (see Box D, page 180)

- Small, tapered diamond bur (#8206) at intermediate high speed (40 000 revs/min) with air/water spray, to open through the occlusal fossa
- Small round burs, sizes 008–016, for caries removal

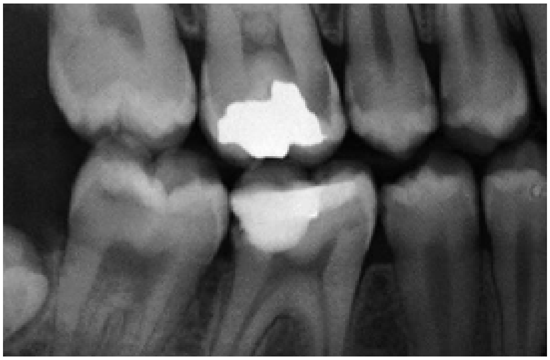


Figure 7.63

A bitewing radiograph of an extreme case of high caries activity, showing three Site 2, Size 1 lesions in the two bicuspids and the mesial of the first molar. Strenuous efforts were made to control the disease first before the lesions were restored.

Figure 7.64

The finished cavity designs immediately prior to restoration. Note that the Site 1, Size 2 amalgam has been removed, because it was faulty, and the lesion is now a combination of a Site 1, Size 2 and a Site 2, Size 1. The occlusal fissures in both bicuspids have been included, very conservatively, in the cavity designs, because there appeared to be further demineralization along them.

Figure 7.65

Another view of the completed cavities, showing that the marginal ridge is still reasonably strong and will be retained.

Figure 7.66

An occlusal view of the restorations immediately upon completion. Note that the two bicuspids were restored with glass-ionomer alone, but the molar was laminated with amalgam, because it was decided that the occlusal load was too heavy for the glass-ionomer to withstand.

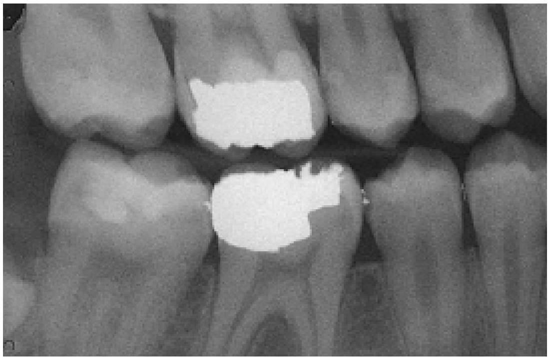


Figure 7.67

A bitewing radiograph of the completed restorations. Note that the lower molars have also been restored with amalgam in the first molar and glass-ionomer in the second molar.

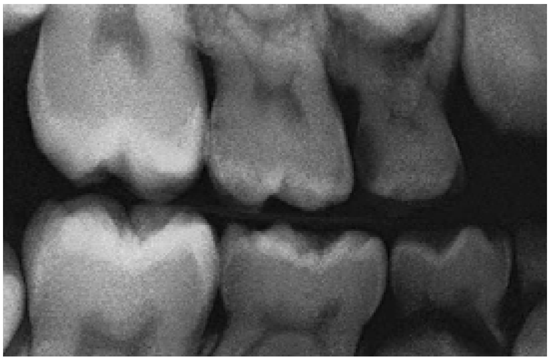


Figure 7.68

A bitewing radiograph of a clinical case, showing a Site 2, Size 1 lesion in the second deciduous molar and a Site 2, Size 2 lesion in the first deciduous molar.

Figure 7.69

The same young patient, showing proximal caries in the distal of two deciduous molars. The occlusal view of the case, showing that the marginal ridge has already broken down in the first molar, thus dictating the classification as a Size 2.

Figure 7.70

The cavity designs are complete on both teeth. Note the tunnel in the second molar and the conservative extent of the slot cavity in the first molar. It has been extended to the buccal and the lingual only far enough to remove all demineralized enamel, but still retains a contact with the adjacent tooth. The cavities are now being conditioned.

Figure 7.71

Short lengths of mylar strip have been placed interproximally as matrices and lightly supported with wooden wedges.

Figure 7.72

The two cavities have been restored using a resin-modified glass-ionomer.

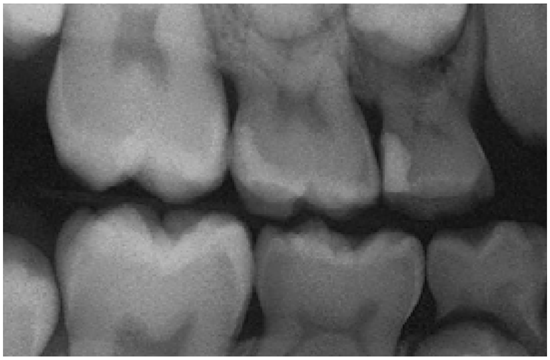


Figure 7.73

A bitewing radiograph to show the completed restorations. Note that there is still a small amount of demineralized dentine on the axial wall of the first molar.

Figure 7.74

The second molar was shed about three years later, and was fortunately made available to the operator. It was sectioned to show the efficiency of the tunnel restoration over the three years.

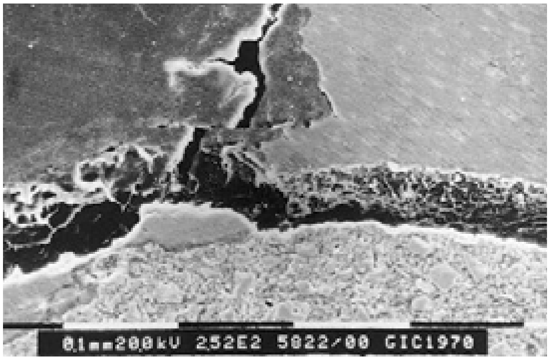


Figure 7.75

The junction of the enamel, dentine and glass-ionomer, close to the occlusal extension of the tunnel restoration, was examined under the SEM. Note the ion-exchange layer still on the dentine, as well as fragments of enamel still attached to the glass-ionomer.

Figure 7.76

A cermet was used to restore tunnel cavities in these two molars. At the time they were photographed they had been in place for 8 years and showed little signs of wear.

Figure 7.77

A bitewing radiograph of the same two tunnels restored with a cermet at 8 years after placement.

Figure 7.78

Two Site 2, Size 1 lesions on the proximal surfaces of the lower second bicuspid have been restored as tunnels using a cermet as the restorative material. They are photographed at about three years of age.

Figure 7.79

The amalgam restoration in the mesial of the first molar requires replacement at this time, thus revealing the proximal surface of the second bicuspid. Note that at this time the surface is still stable, even though it is stained and rough. It is assumed that the surface has been remineralized, and is therefore fluorapatite, and more resistant to further demineralization.

Figure 7.80

A similar situation in another patient, where replacement of a large amalgam offered the opportunity of re-examining the distal of the second bicuspid. The tunnel cavity had been restored with a cermet approximately five years previously.

Figure 7.81

A bitewing radiograph of the case shown in Figure 7.80 just prior to the replacement of the amalgam.

- Long-shank bur for difficult access
- Access for hand instruments is limited, but the MC 1 double-bladed chisel may be useful

Preparation and restoration

- Use a small tapered diamond bur (#8206) at intermediate high speed under air/water spray, and enter from the occlusal fossa immediately medial to the marginal ridge. Angle the bur towards the lesion, and progress outwards and gingivally until the lesion can be identified.
- Upright the bur towards the marginal ridge, and lean it buccally and lingually to develop a funnel-like approach, with a triangular entry from the occlusal, to improve visibility and access. Good illumination and magnification are desirable.
- Use small round burs at slow speed to remove infected dentine from the full circumference of the lesion. Take care to clean the buccal, gingival and lingual walls, but leave affected dentine on the axial wall undisturbed.
- Carefully examine the enamel wall. If it is not cavitated, do not prepare it any further. If there is cavitation, protect the adjacent tooth with a metal matrix band and remove friable enamel rods carefully with a small hand instrument such as the MC I chisel. There is no need to remove all demineralized enamel, because it may remineralize. Leave the matrix in place during restoration.
- Condition the cavity and restore with the selected material. The most suitable material for the restoration will be a high-strength, auto cure, radiopaque glass-ionomer with the highest physical properties. A resin-modified material is satisfactory, provided it can be adequately light-activated.
- Place the glass-ionomer with a capsule or a disposable syringe to optimize adaptation to the cavity floor and walls. Place it incrementally, and use a small plastic sponge to tamp the cement to place. Use an occlusal matrix or a gloved finger, lightly vaselined, as a matrix to apply additional pressure.
- Cut back the cement and laminate the occlusal entry with composite resin only if there is doubt about the ability of the cement to withstand the occlusal load.

Site 2, Size 1 – 'slot'

One alternative approach is the preparation of a slot cavity, and this should be used when the lesion is less than 2.5 mm from the crest of the marginal ridge. Generally the lesion will be obvious to visual examination, particularly when using magnification, because of the discoloration under the marginal ridge (Figures 7.82 to 7.85). Alternatively, study the bitewing radiographs. The basic principles of cavity design remain the same, with the object of removing only that tooth structure that has broken down beyond the possibility of remineralization. If this is allowed to dictate the extent of the cavity there will be many occasions with this design where there is still a sound contact with the adjacent tooth in one part or another. It is desirable to retain this to ease the problems of maintaining a good firm contact area and thus minimizing the dangers of food impaction and retention.

The outline form will be dictated entirely by the extent of the breakdown of the enamel. Remove only that which is friable and easily eliminated without applying undue pressure. Remaining demineralized enamel will generally heal satisfactorily. Retention will again be through adhesion, so that it is only necessary to clean the walls around the full circumference of the lesion. Leave the axial wall, because it will be affected dentine only, and will remineralize over a short period of time. Its removal will be a hazard to the pulp, and that is no doubt already inflamed.

Instruments required (see Box D, page 180)

- Small, tapered diamond (#8206) at intermediate high speed (40 000 revs/min) with air/water spray, to open the outer slope of the marginal ridge. Tapered diamond #3206 to polish
- Small round burs, sizes 008–016, for caries removal

Preparation and restoration

- Use a small tapered diamond bur at intermediate high speed under air/water spray, and enter from the outer slope of the marginal ridge. Open buccally and lingually only as far as is required to identify the cavitated enamel. Protect the adjacent tooth with a metal matrix band, and leave this in place during restoration.

Site 2, Size 1 Slot cavity

Figure 7.82

A laboratory model showing a first bicuspid with a proximal lesion that is less than 2.0 mm from the crest of the marginal ridge. It is suggested that a slot cavity design would be logical.

Figure 7.83

The first bicuspid, showing the lesion prior to mounting.

Figure 7.84

The cavity has now been prepared to its full extent using the instruments recommended in Box D, page 180. Note that there is still a contact between the two adjacent teeth, because the cavity has been extended only as far as the fully demineralized enamel.

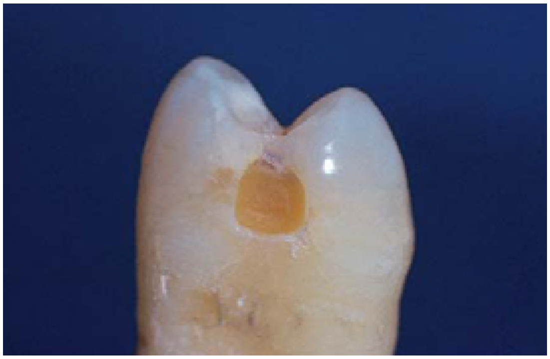


Figure 7.85

A proximal view of the prepared cavity. Note that there is still some demineralized enamel on the proximal surface that is expected to remineralize.

Remove friable enamel rods carefully with a small hand instrument such as the MC I chisel. Retain a contact with the adjacent tooth wherever possible.
- Use small round burs at slow speed to remove infected dentine from the full circumference of the lesion. Leave affected dentine undisturbed on the axial wall, because it will remineralize and protect the pulp.
- Condition the cavity and restore with the selected material. The most suitable material for the restoration will be a high-strength, auto cure, radiopaque glass-ionomer with the highest physical properties. A resin-modified material is satisfactory, providing it can be adequately light-activated.
- Place the glass-ionomer with a capsule or a disposable syringe to optimize adaptation to the cavity walls. Place incrementally and use a small plastic sponge to tamp the cement to place. Use an occlusal matrix or a gloved finger, lightly vaselined, as a matrix to apply additional pressure.
- Cut back the cement and laminate the occlusal entry with composite resin only if there is doubt about the ability of the cement to withstand the occlusal load.

Site 2, Size 1 – 'proximal approach'

A further very conservative approach to the restoration of a proximal lesion can be achieved, on limited occasions only, when the proximal surface of a posterior tooth becomes accessible at the time of cavity preparation in an adjacent tooth (Figures 7.86 to 7.90). The lesion may have been revealed through radiographs or may be noted only during cavity preparation. The larger cavity in the first tooth will normally need to be of reasonably generous proportions to allow room for manoeuvre; but when such an approach is possible, it leads to considerable conservation of natural tooth structure.

In view of the normal direction of the progress of a carious lesion through the enamel and down

Site 2, Size 1, proximal approach cavity

Figure 7.86

A laboratory model showing the proximal surface of the second bicuspid exposed by the preparation of a large Site 2, Size 3 cavity in the adjacent first molar. There is a lesion on the distal of the second bicuspid that is now available for restoration with very limited removal of sound tooth structure. There is a trace of zinc oxide and eugenol left behind in the cavity from a previous exercise.

Figure 7.87

A small tapered diamond bur is being used to gain access to the lesion at intermediate high speed under air/water spray.

Figure 7.88

A long-shank endodontic round bur is now being used to remove remaining infected dentine.

Figure 7.89

The completed cavity design. Note that there is demineralized enamel in some areas around the lesion; but as these surfaces are still smooth, it is expected that they will remineralize, and therefore do not need to be removed – provided the disease is cured.

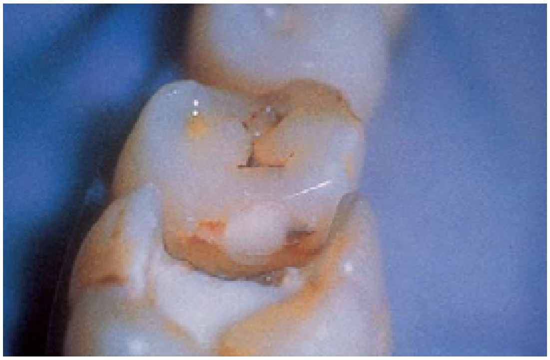


Figure 7.90

The completed restoration. A fast-set high-strength auto cure glass-ionomer was used, because it is radiopaque and will not be under occlusal load.

the dentine tubules (Figure 7.42), it is not difficult to clean the cavity, trim the enamel walls and eliminate infected dentine. Note that it is only necessary to remove enamel that is broken down beyond remineralization. There will often be a residual area of stained enamel around the circumference of the lesion, and this should be retained, because it is quite capable of being remineralized and healed. As this entire restoration will probably be hidden and disguised by the restoration in the adjacent tooth, it is essential to use a radiopaque glass-ionomer, and, in view of probable difficulties in access for light-activation, the material selected should be an auto cure.

Instruments required (see Box D, page 180)

- A small tapered diamond bur (#8206) at intermediate high speed (40 000 revs/min) under air/water spray to open the enamel lesion

- Small round burs, sizes 008–016, for caries removal and a #3206 to polish
- Use a long-shank bur for difficult access
- Access for hand instruments is limited, but the MC 1 double-bladed chisel may be useful

Preparation and restoration

- Enlarge access into the enamel lesion using a small tapered diamond bur at intermediate high speed under air/water spray with good illumination and magnification (Figures 7.86–7.90).
- Remove the infected dentine with small round burs at slow speed. Burs with long shanks may be required for correct bur placement. Make sure the circumference of the cavity is completely clean to allow for the ion-exchange adhesion.
- Leave affected dentine undisturbed on the axial wall, because it will remineralize and protect the pulp.
- Condition the cavity, and use a short length of a mylar or metal strip as a matrix, supported as required with a wedge.
- Restore using a high-strength, auto cure radiopaque glass-ionomer so that it can be monitored radiographically in future.
- Contour and polish immediately prior to placing the adjacent restoration.

Site 2, Size 2

This category recognizes the increasing size of the lesion, and in many cases it will be the result of replacement dentistry where a failed GV Black Class II restoration has to be repaired or replaced. There will, of course, be neglected new lesions to be dealt with; but on those occasions the design will be much the same, although often the occlusal fissure can be left uninvolved.

When the restoration reaches these dimensions it is likely that there will be a serious need to laminate the glass-ionomer base, because the occlusal load will be beyond that which can be safely handled over the long-term with the cement alone. This suggests that the lamination technique will be the method of choice, and this is fully discussed in Chapter 6. However, it will be reviewed here in relation to a relatively small restoration using the same principles that were discussed in detail before. The only significant factor will be the possibility of a sound enamel margin at the floor of the gingival box. If this exists there is no need to leave the glass-ionomer exposed in that area, although there may still be an argument in favour of this, bearing in mind the potential benefit of the ion-exchange demonstrated with a glass-ionomer restoration (Figures 7.91–7.98).

Site 3 lesions

It is suggested that lesions around the circumference at the cervical of the crowns of teeth are becoming more prevalent, and range from cervical hypersensitivity caused by erosion to recurrent lesions beyond existing restorations, to interproximal root-surface lesions. Non-carious tooth loss is a regular cause of problems in this region, and is becoming far more common. The causes range from abrasion and erosion to abfraction, and the end-result will range from hypersensitivity with little obvious tooth loss to extreme loss of tooth structure, all the way to pulp exposure.

Cervical hypersensitivity is almost certainly the result of demineralization of exposed root-surface dentine by chemical means. Low pH drinks in particular will demineralize the surface to a depth of 2 to 3 μ, leaving unsupported collagen fibres exposed. If the teeth are then cleaned vigorously with a tooth brush the surface collagen will be removed before it has had a chance to remineralize. This is then likely to leave the dentine tubules open, and alterations in osmotic pressure will stimulate a pain response. There are a number of chemical methods available to close over tubules and overcome this problem. However, as always, the best treatment is to recognize the cause and remove it.

Non-carious tooth loss can continue in these regions, as a result of either toothbrush abrasion or abfraction, without necessarily developing hypersensitivity. Abfraction is thought to be the result of flexure of the tooth arising from undue

Site 2, Size 2 restoration

Figure 7.91

A laboratory model, showing a small lesion in the mesial of the upper first bicuspid, in which an old amalgam is to be replaced with a composite resin. A glass-ionomer lamination technique will be used for the restoration. Note that the occlusal groove has been extended down into the dentine at the distal to eliminate a small amount of demineralized dentine related to an early Site 2, Size 1 lesion at the distal proximal contact.

Figure 7.92

A short length of mylar strip has been placed interproximally and lightly supported with a wooden wedge. The cavity can now be conditioned and restored with a resin-modified glass-ionomer, because this section of the restoration will be involved in the aesthetic end-result.

Figure 7.93

The glass-ionomer has now set, and the cavity is redesigned for restoration with composite resin. Note that the glass-ionomer has been left in the proximal box, protecting the gingival floor, because the enamel was judged to be too weak to sustain adhesion to the composite resin.

Figure 7.94

The enamel margin has been lightly bevelled in appropriate areas and is now etched ready for adhesion to the enamel. There is no need to etch the glass-ionomer, because the resin content is sufficient to provide adhesion with the composite resin.

Figure 7.95

The matt finish on the enamel shows the level of etching achieved, and the enamel and glass-ionomer are now being painted with a low-viscosity resin–enamel bond. This will be light-activated prior to placing the composite resin.

Figure 7.96

The first increment of composite resin is placed in the buccal gingival corner and light-activated through the buccal cusp to encourage shrinkage towards the tooth structure.

Figure 7.97

The completed restoration following incremental build-up throughout.

Figure 7.98

The tooth has now been sectioned to show the effect of the lamination technique. Note the substantial layer of glass-ionomer across the entire floor; it is exposed to the oral environment at the gingival of the proximal box. Note the minor extension of the glass-ionomer into the lesion related to the distal contact area. It is assumed that this lesion will now heal.

Site 3, Size 0

Figure 7.99

The bridge shown here has been in place for many years, but there is now a rather deep sharply angled lesion along the gingival margin of both the second bicuspid and the canine. The gingival tissue is apparently falling into the lesion, suggesting that it is not simply an erosion lesion.

Figure 7.100

The gingival tissue has been removed from the lesion, and the margin has been treated with trichloracetic acid to control haemorrhage. This reveals the depth and extent of the lesion, which is tentatively identified as having been caused by abfraction.

occlusal load (Figures 7.99, 7.100). If the root of a tooth is reasonably slim and is well supported by alveolar bone it must be regarded as flexible, at least to a degree. If it is then subjected to considerable lateral load, beyond that which it was designed to sustain, it is likely to flex and bend. This can cause compression or tension at a point just above the crest of the alveolar bone, leading to displacement of enamel rods or segments of mineralized dentine, and these can then be lost. The undue load can often be traced to a buccal or lingual cusp that remains in contact in a lateral excursion beyond the position at which it is normally disarticulated. The resultant lesion will often be different from an erosion, lesion, inasmuch as it will be deep, with a sharp angle at the base, and will often extend subgingivally. Treatment will always begin with identification and elimination of the occlusal problem, followed by restoration with glass-ionomer, because this appears to be able to withstand any remaining flexure.

Root-surface caries will occur, mostly interproximally, on exposed root surfaces; but it is possible for it to be found anywhere around the full circumference (Figures 7.101, 7.102). Enamel is a heavily mineralized material, and the acid attack of caries will penetrate relatively slowly over a narrow area related to plaque accumulation. The root surface, on the other hand, is cementum and dentine only, and these are relatively lightly mineralized. This means that the same acid attack will lead to a much larger area of involvement on the root surface (Figures 7.103, 7.104). Diagnosis can be difficult, because the early lesion is often just a broad surface softening through demineralization without discoloration or any other indication of its presence. As long as there is no cavitation, it is relatively simple to eliminate the disease and remineralize the area. However, if, during diagnosis, a sharp probe is used, the surface is very easily indented and damaged, and this means that a Site 3, Size 0 lesion, which may be subject to simple remineralization, can immediately be converted

Root surface caries

Figure 7.101

There is an early root surface lesion at the gingival of the upper canine. It is classified as Size 0 on the assumption that it can be healed through control of the disease. It may be a good idea to polish lightly and fluoridate the area; but patient instruction in oral hygiene in conjunction with other control measures may well be sufficient to heal it. Observation over the next six months will lead to a final decision.

Figure 7.102

There are early signs of root-surface caries at the gingival margin of the lower first molar. It is suggested that the institution of vigorous preventive measures along with fluoride may be sufficient to arrest and heal these demineralized areas. This is classed as a Size 0 Lesion at this stage, but this may be revised after 6 months' observation.

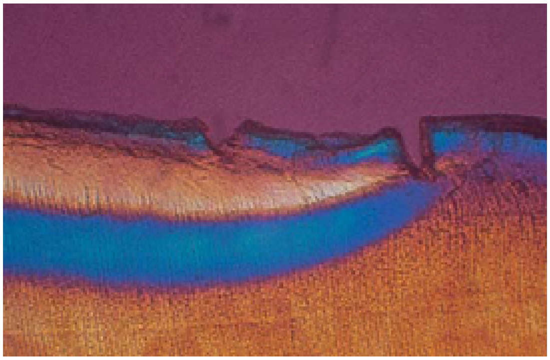


Figure 7.103

A section through a root-surface caries lesion that has been immersed in quinoline to show the extent of the demineralization. On the surface is the cementum, which remains reasonably intact. The dentine immediately below, however, has been demineralized to such an extent that, at the level of the blue colour, there has been a loss of up to 40% of the mineral (courtesy Dr J McIntyre).

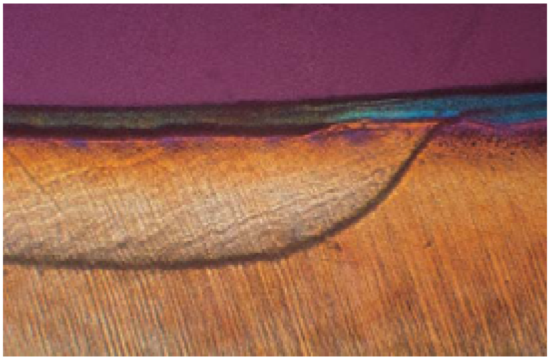


Figure 7.104

The same specimen as shown above, this time immersed in water. Note that the lesion is primarily sub-surface below the cementum, and is not really as clearly defined as it would be in the presence of enamel (courtesy Dr J McIntyre).

into a Size1, which requires restoration to prevent further plaque accumulation.

The problem area for root-surface caries is interproximally, because it is more difficult to diagnose and to treat. Control and elimination of the disease followed by remineralization is the first method of choice. However, as the patients age and their general health declines, the problems of control increase. Routine recall with careful observation is essential, because this can be one of the earliest signs of loss of salivary flow. The patient will not necessarily be aware of this; but polypharmacy can readily modify both the quantity and quality of the saliva, and caries activity will re-establish rapidly.

When the interproximal surfaces become involved early treatment is imperative. The further the lesion has advanced the more difficult it is to restore. Visualization is difficult, and it is hard to define the outline of the lesion. If the lesion is to be effectively sealed it is essential to clean the entire periphery; but care must be taken to leave the axial wall untouched, even though it is still soft and demineralized. The pulp is relatively close to the surface in the root of a tooth, and it is difficult to avoid involving it in the presence of root-surface caries.

All lesions in this category should be restored with glass-ionomer, either auto cure or resin-modified. These are ideal materials for this situation, because the restorations will not be under occlusal load; and they have all the advantages of the continuing ion-exchange, including the potential for remineralizing the floor of the cavity. They have been shown to have exceptional longevity under these circumstances.

Site 3, Size 0

These lesions do not require restoration, but they do need careful diagnosis and treatment planning to ensure that they will no longer progress. All the potential causes have been discussed above, so effective treatment should not be difficult to achieve.

Patient education is of primary importance, because the lesion will be patient-caused. Hypersensitivity can be treated with one of a number of mineralizing solutions; but if the cause is not overcome the lesion will inevitably progress, and success will be transitory only. At the same time it is important for the operator to examine the occlusal envelope, particularly lateral excursions, so that the possible causes of abfraction can be eliminated through a simple occlusal adjustment.

Site 3, Size 1

The most common lesion in this category will be the result of advancing erosion, abrasion or abfraction (Figures 7.105 to 7.116). It is always wise to both eliminate the cause and seal the lesion before it becomes too deep. Treatment should be kept very simple, because a glass-ionomer will adhere very effectively to the burnished sclerotic surface of the root through the ion-exchange mechanism (Mount 1990b). This means that any form of cavity preparation, apart from conditioning, is strictly contra-indicated, because a smooth surface is the best for any form of chemical adhesion.

There may, of course, be a small carious lesion developing at the gingival margin. This will be a sure sign of the presence of active disease, and vigorous measures should be undertaken first to overcome this. Treatment will then involve removal of the surface infected dentine and placement of a glass-ionomer restoration, either auto cure or resin-modified. There is a variety of shades available in both types, so colour matching should not be a problem.

Instruments required (see Box D, page 180)

- for the erosion lesion there will be no instruments required, because the cavity should not be prepared at all.
- for the small carious lesion use a small round bur only, to clean the walls sufficiently to allow ion-exchange adhesion.

Preparation and restoration

- for the erosion lesion, clean lightly with a slurry of pumice and water on a small rubber cup to remove any plaque on the surface of the lesion and to ensure complete adaptation of the glass-ionomer to the tooth.

Site 3, Size 1 lesions

Figure 7.105

There are three erosion/abrasion lesions at the buccal margins of the canine and two bicuspids. Although they are reasonably extensive they will be classified a Size 1, because they are relatively simple to restore with a resin-modified glass-ionomer.

Figure 7.106

The surfaces of the lesions are lightly scrubbed with a slurry of pumice and water to remove the pellicle.

Figure 7.107

There was slight damage to the gingival tissue during the pumicing, so a small quantity of trichloracetic acid (see Box C, page 85) was applied to the gingival tissue to arrest the haemorrhage. The surface could then be conditioned with 10% polyacrylic acid for 10 seconds to prepare the surface for the ion-exchange adhesion.

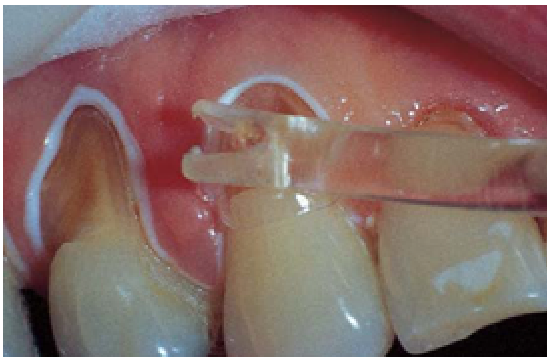


Figure 7.108

A series of translucent matrices was tested and modified prior to placement of the cement to ensure the glass-ionomer would be positively adapted to the tooth.

Figure 7.109

The glass-ionomer was syringed to place, the matrix adapted and the cement light-activated for 20 seconds. After removal of the matrix the restoration was light-activated for a further 20 seconds, and it was then ready for contouring and trimming using very fine diamond burs under air/water spray.

Figure 7.110

The finished restorations immediately after finishing. As soon as they had been contoured and polished an unfilled low-viscosity resin–enamel bond was painted over each restoration. This effectively sealed the glass-ionomer against water loss in the short term and also smoothed the surface and filled any remaining scratches and porosities.

Figure 7.111

The same restorations 18 months after placement.

Figure 7.112

The same restorations three years after placement. Note that there appears to be a minor colour shift in the two bicuspids; but there has also been a falling off in the patient's hygiene routines, which may account in part for the change.

Figure 7.113

Three Site 1, Size 1 erosion lesions on upper anteriors, which will be restored with an auto cure glass-ionomer.

Figure 7.114

The lesions have been restored using a Type II.1 auto cure glass-ionomer. They were photographed about 12 months after placement.

Figure 7.115

The same patient as is shown in Figures 7.113 and 7.114. The six upper anterior teeth were restored at the same time, and this photograph, taken 12 months later, shows that the aesthetic result was satisfactory over all of them.

Figure 7.116

The same restorations shown in the previous illustration photographed 10 years after placement. It is apparent that the patient's oral hygiene techniques have not been modified, because there are signs of wear on all three restorations. In addition there has been a degeneration in the colour of the natural teeth, so that the colour match is no longer ideal.

- in the presence of active caries, clean the walls around the full circumference but leave the axial wall to remineralize under the glass-ionomer.
- condition the surface of the cavity with 10% polyacrylic acid for 10 seconds only, wash well and dry lightly.
- select a suitable matrix and pre-form as required.
- mix the appropriate material, in a capsule for preference.
- syringe the glass-ionomer on to the tooth surface and apply the matrix to adapt the material well and positively to the surface of the tooth.
- light-activate or allow the glass-ionomer to set. Check the excess around the periphery of the matrix to see that it is properly set.
- remove the matrix and immediately apply a generous coating of a low-viscosity resin as a sealant. This is essential for the auto cure, but is still a good idea for the resin-modified material.
- use a sharp blade to trim an auto cure material minimally before light-activating the resin seal. Use fine diamonds under air/water spray to contour a resin-modified material and then seal it again with the low-viscosity resin seal.
- polish the restorations after the glass-ionomer has matured only if it is essential. If the matrix was properly applied subsequent polishing is often not required.

Site 3, Size 2

These lesions will generally be cavities resulting from active caries (Figures 7.117 to 7.124). They will vary from the Size 1 lesion only in relation to their size, and they will be more of a challenge to restore. The usual instrumentation will be required to remove the demineralized infected dentine on the surface before restoring. Clean the walls only, although, almost certainly, there will be affected dentine remaining on the floor of the cavity. However, as long as the margin is sealed against microleakage, the restoration will be effective and the affected dentine will heal.

Instruments required (see Box D, page 180)

- for this larger carious lesion it may be necessary to extend the margins a little using a small tapered diamond bur (#8206).
- use a small round bur to clean the walls sufficiently to allow ion-exchange adhesion.

Preparation and restoration

- in the presence of active caries clean the walls around the full circumference, but leave the axial wall to remineralize under the glass-ionomer.
- condition the surface of the cavity with 10% polyacrylic acid for 10 seconds only, wash well and dry lightly.
- select a suitable matrix, and pre-form as required.
- mix the appropriate material, in a capsule for preference.
- syringe the glass-ionomer on to the tooth surface and apply the matrix to adapt the material well and positively to the surface of the tooth.
- light-activate or allow the glass-ionomer to set. Check the excess around the periphery of the matrix to see that it is properly set.
- remove the matrix, and immediately apply a layer of low-viscosity resin as a sealant. This is essential for the auto cure, but still a good idea for the resin-modified material.
- use a sharp blade to trim an auto cure material minimally before light-activating the resin seal. Use fine diamonds under air/water spray to contour a resin-modified material and then seal it again with the low-viscosity resin seal.
- polish the restorations after the glass-ionomer has matured only if it is essential. If the matrix was properly applied, subsequent polishing is often not required.

Site 3, Size 3

These lesions are generally root-surface lesions on the interproximal surfaces of anterior or posterior teeth (Mount 1988). Under these circumstances it will often be prudent and conservative to enter the lesion from either the buccal or the lingual rather than from the occlusal. The decision concerning the side of entry will be dictated primarily by the position of the lesion and secondarily by the need for access and convenience (Figures 7.125 to 7.128). It is, of course, possible in a young patient to approach an initial lesion that lies immediately under the contact

Site 3, Size 2 lesions

Figure 7.117

At examination the amalgam restoration at the gingival of the first bicuspid appeared to be standing a little out of the cavity. Application of pressure expressed plaque out from around the amalgam. It seems likely that, in the absence of adhesion, as the crown of the tooth flexed under occlusal load, plaque had been able to build up under the restoration. Note that there appeared to be no active caries.

Figure 7.118

The loose amalgam has been removed and the cavity cleaned and conditioned ready for placement of a glass-ionomer restoration.

Figure 7.119

A soft tin matrix was adjusted to shape and a Type II.1 auto cure glass-ionomer was syringed in to the cavity. The matrix was placed to ensure positive pressure to adapt the cement to the cavity floor and walls.

Figure 7.120

Excess cement around the matrix was used to test the degree of set of the glass-ionomer. When it was hard enough to flick off, the matrix was removed and the restoration painted immediately with a low-viscosity resin–enamel bond. This shows the completed restoration just prior to removal of the rubber dam.

Site 3, Size 3

Figure 7.121

There is a failed composite resin restoration at the gingival proximal margin of the upper canine. The Site 3 lesion is generally interproximal root caries; so, even though access is simplified by loss of the adjacent tooth, this receives the same classification.

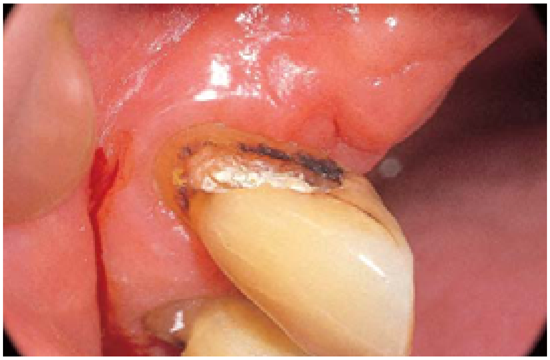


Figure 7.122

The restoration has been removed and the marginal leakage becomes apparent. The root surface is becoming carious again, probably because the patient has a high caries index, and this is complicated by the presence of a removable partial denture.

Figure 7.123

A Type II.1 auto cure glass-ionomer was used to restore the lesion, because there was a need for aesthetics in this position. The soft tin matrix was preformed to the shape of the root before mixing the cement.

Figure 7.124

The completed restoration approximately 10 years after placement. Note the improvement in hygiene and therefore in tissue tone. There has been a slight shift in the colour of the natural tooth crown.

Figure 7.125

There is root surface caries at the distal of the exposed root of the lower right first bicuspid. This is a mirror image, so the picture is a little confusing.

Figure 7.126

The cavity preparation is complete. Note that access has been at the expense of enamel towards the buccal surface, because it is essential to have access for good visibility. The walls around the circumference are clean, but the axial wall has been left in demineralized affected dentine because of the risk of exposure of the pulp.

Figure 7.127

The short length of metal matrix strip that was used to protect the adjacent tooth during cavity preparation has been replaced and supported with a wooden wedge. It will now act as a matrix for the glass-ionomer. The cavity is being conditioned prior to restoration.

Figure 7.128

The cavity was restored using a high-strength, fast-set auto cure glass-ionomer, and this shows the completed restoration immediately prior to removal of the rubber dam.

area with this design. However, the closer the cavity is to the marginal ridge, the more likely it is that the ridge will fail at a later date. The lesion in the older patient will be beyond the cemento-enamel junction, and therefore well below the contact area, so that remaining tooth structure is less likely to fail subsequently.

The problem will usually be related to root-surface caries or to an open margin on a crown or gold inlay. It may be recurrent caries in relation to an overhanging margin on an old restoration. A careful history should be elicited, because such lesions are often related to xerostomia or alternatively to a functionally opening contact. Either way, the cause should be dealt with first, with treatment to follow.

In the case of a functionally opening contact the condition of the previous restoration will need to be carefully assessed. With an old amalgam, for example, the question may be whether to replace the entire restoration or to restore the lesion through a tunnel-type cavity design. If the occlusion, proximal contour and contact and the margins of the original restoration are sound, it may be far kinder to an elderly patient to provide minimal treatment in the form of a tunnel. For restoration of a lesion under a full crown the tunnel is only justified when the remaining margins are entirely acceptable and caries-free.

As it may well be difficult to monitor the restoration in the future without radiographs, it is recommended that a radiopaque material should be placed. Provided there is sufficient access for the correct positioning of an activator light, a resin-modified material may be preferred, particularly in anterior teeth.

Instruments required (see Box D, page 180)

- Small, tapered diamond bur (#8206) at intermediate high speed (40 000 revs/min) under air/water spray
- Small round burs, sizes 008–016, for caries removal
- Long-shank round burs may be required for deep access
- Access for hand instruments is limited

Preparation and restoration

- Enter the lesion from the buccal or the lingual as the position of the carious lesion dictates, using the small tapered diamond stone at intermediate high speed under air/water spray.
- Use a short length of a metal matrix to protect the adjacent tooth while working. Wedge the matrix carefully when placing the cement.
- Begin slightly occlusal to the lesion, and move interproximally and gingivally until the lesion is clearly visible. Sacrifice sufficient tooth structure or old restoration to allow access and convenience form without unduly weakening the marginal ridge.
- Use small round burs at slow speed to remove all infected dentine and develop clean walls around the entire circumference. Leave the axial wall, even though it is demineralized.
- If possible, retain the wall at the opposite side from the entry, to provide a positive finishing line for the restoration.
- Restore using a radiopaque glass-ionomer. If access is available for correct placement of the activator light, use a resin-modified material.
- Trim and contour carefully after placement to ensure there is no overhang or overcontour.
- Seal with a very-low-viscosity light-activated resin–enamel bond.

Site 3, Size 4

In a situation where a cervical lesion involves two or more surfaces it will be classified as a Size 4. The basic principles will remain the same as for the Size 3 lesion, but access and cavity design will be somewhat more complex (Figures 7.129 to 7.131).

The greatest problem is likely to be the construction of a suitable matrix. If an auto cure material is to be placed then it may be possible to preform a matrix in soft tin or similar. Wrap this around the tooth and support it with greenstick compound. Before it is positioned cut a hole at a convenient site with a round 8 bur sufficiently large to admit the tip of the mixing capsule or disposable syringe. Apply a thin coat of a separating medium to the inner surface of the metal matrix so that the glass-ionomer does not stick to it. Once the matrix is firmly positioned the cement can be syringed into place and allowed to set, and then the matrix can be removed.

If a resin-modified material is to be used it can be placed incrementally, and each increment can be light-activated until the entire restoration is

Site 3, Size 4

Figure 7.129

This elderly patient is suffering rampant root-surface caries. Every effort will be made to try to control the disease; but in failing health the problems are great. Existing restorations are failing, and the lesions on the central and lateral incisors should be classed as Size 4, because they each involve three surfaces at least.

Figure 7.130

The prepared cavities, in which care was taken to ensure that the margins were in sound tooth structure, but the axial walls were left as demineralized dentine because of the fear of exposing the pulp.

Figure 7.131

The lesions were restored using a resin-modified glass-ionomer. This was easier to place incrementally in these complex cavities, and it is also more resistant to dehydration in a patient with a reduced salivary flow.

fully cured. A translucent matrix made from a mylar strip will enhance adaptation, but the material must be available to the light source at all times.

Instruments required (see Box D, page 180)

- Small, tapered diamond bur (#8206) or a diamond cylinder (#8214) at intermediate high speed (40 000 revs/min) with air/water spray, to open into the lesion.
- Small round burs, sizes 008–016, for caries removal.
- Long-shank round burs may be required for difficult access.

Preparation and restoration

- Enter the lesion from the buccal or the lingual as the position of the carious lesion dictates, using the small tapered diamond stone at intermediate high speed under air/water spray.

- Use a short length of a metal matrix to protect the adjacent tooth while working. Wedge the matrix carefully when placing the cement.
- Begin slightly occlusal to the lesion, and move interproximally and gingivally until the lesion is clearly visible. Sacrifice sufficient tooth structure and/or old restoration to allow access and convenience form.
- Use small round burs at slow speed to remove all infected dentine and develop clean walls around the entire circumference. Leave the axial wall, even though it is demineralized.
- The complexity of the cavity will require the construction of a complex matrix.
- Restore using a radiopaque cement. If access is available for correct placement of the activator light, use a resin-modified material.
- Trim and contour carefully after placement to ensure there is no overhang or overcontour.
- Seal with a very-low-viscosity light-activated resin–enamel seal.

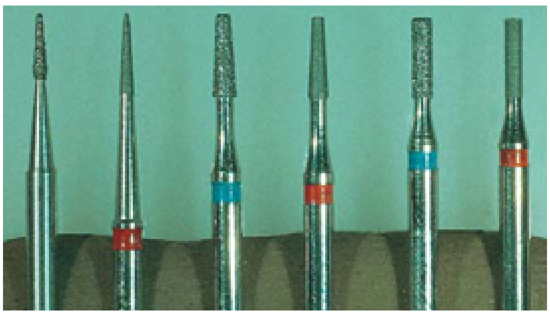
BOX D MINIMAL INTERVENTION CAVITY PREPARATION KIT

The basic concept for minimal intervention dentistry is preservation of natural tooth structure as far as possible. If the disease has progressed to the stage where the surface of the enamel or root dentine has become cavitated then some form of surgical intervention is required. However, the design of the cavity should be limited to access to the lesion and removal of the infected dentine followed by sealing of the margin to prevent microleakage. The following burs have been selected from the Intensiv range as a kit suitable for such limited surgery.

Diamond burs – to be used at intermediate high speed

	Catalogue No.	**ISO #**
Very fine tapered bur to explore fissures	80µ #8107	806.314.159.524
	25µ #3107	806.314.159.514
Tapered diamond to enlarge a cavity	80µ #8206	806.314.168.524
	25µ #3206	806.314.168.514
Diamond cylinder to extend further	80µ #8214	806.314.107.524
and clean the walls for lamination	25µ #3214	806.314.107.514

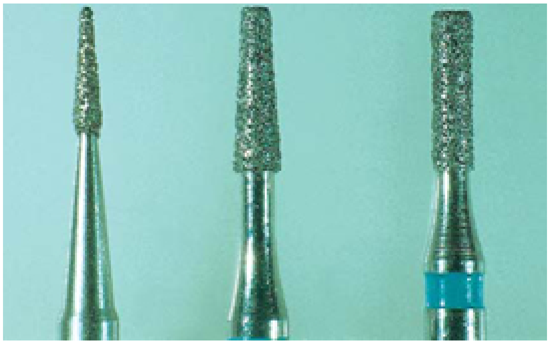
All three shapes are provided in two grit sizes. The coarse diamonds have a grit size of 80µ and are used to prepare the cavity outline. The finer diamonds have a grit size of 25µ and are used to lightly polish the cavity walls and margins. To obtain optimum adhesion between the restoration and the tooth, it is necessary for the surface to be as smooth as possible. Light polishing with a 25µ diamond has been shown to provide the optimum surface.



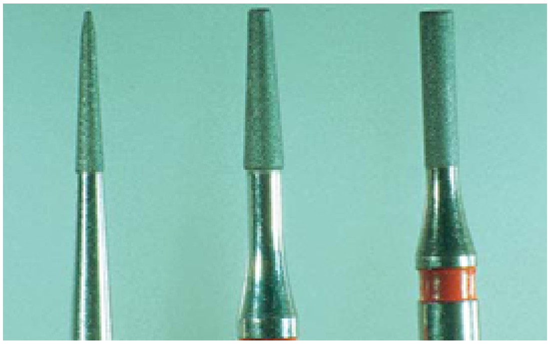
(*a*) The full kit of diamond burs recommended for minimal intervention cavities

continued on the next page

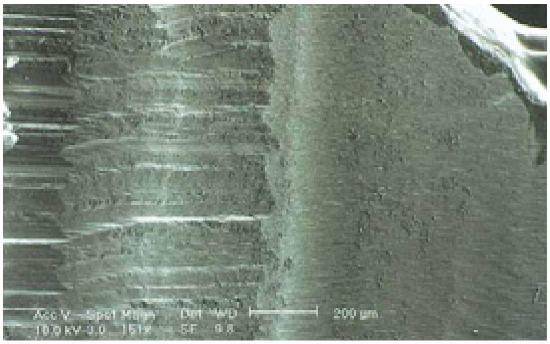
BOX D *continued*



(*b*) The three 80μ diamonds recommended for initial opening of a cavity



(*c*) The three 25μ diamonds recommended for final finishing of enamel margins



(*d*) A scanning electron micrograph shows the junction between a surface prepared by an 80μ diamond (left) and a 25μ diamond (right).

Steel burs – to be used at slow speed

Standard-length burs –	very small cavities	008
	small cavities	012
	large cavities	016

(see Mount and Hume, *Preservation and Restoration of Tooth Structure*, Mosby, London, 1998, Chapter 6, for detailed rationale for bur selection.)

BOX E MATRICES

Site 1, occlusal restorations

- The simplest matrix former is the tip of a gloved finger. After syringing the glass-ionomer into place apply a very light coating of vaseline (petroleum jelly) to the tip of the gloved finger, wipe off any gross excess and apply the finger over the material and apply pressure. Hold in place for approximately 1.5 minutes then roll the finger sideways off the restoration and the rubber of the glove will separate from the glass-ionomer.
- There are commercially available preformed occlusal matrices suitable for most situations.

Site 2, proximal restorations

- If the matrix requires considerable strength, use a conventional mild steel matrix strip in a conventional matrix holder or cut and contoured to fit. Apply a thin coat of low viscosity light activated resin bond or vaseline to the inner surface first before placing it to prevent the glass-ionomer from sticking to it.
- If the matrix requires only moderate strength, use a regular mylar strip, cut and contoured to fit as required.

Site 3, cervical restorations

- There are preformed translucent matrices for use when placing a resin modified material. Modify as required in advance.
- There are preformed soft tin matrices available which already have a thin separating medium applied to the inner surface. Preform and modify as required in advance.
- For complex two and three surface restorations use a heavier tin foil and apply a separating medium to the inner surface before placing in position. Cut a hole through the tin in a strategic position with a round bur and possibly support the matrix with greenstick compound or similar. The glass-ionomer can now be syringed into place through the hole.

BOX F WEDGES

There are two reasons for using a wedge. It can be used to support the gingival margin of a matrix band or to gain space between two teeth and thereby improve the strength of the contact point. It can fulfil both purposes at once.

To support the gingival margin of a matrix band

- Use a wooden wedge, but take care not to distort the matrix band.
- If the matrix band is frail and likely to distort under pressure, use a small pledget of cotton wool soaked in a light-activated resin bonding agent. Place this interproximally as required and light-activate. This will give sufficient support to the matrix to allow positioning of the glass-ionomer cement without displacement or production of an overhang.
- If the matrix is of heavy tin foil, support as required with greenstick compound.

To gain space between two teeth

- Plan ahead of time and place an orthodontic rubber ring 48 hours before restoration.
- Place a wooden wedge before beginning cavity preparation. Adjust the pressure periodically prior to placing the matrix.
- If placing a posterior composite resin restoration, use a plastic light-transmitting wedge in the same manner.

8 Instructions for dental assistants

With glass-ionomer cements as with all dental materials, the dental assistant plays an important part in correct handling and clinical success. This chapter is therefore designed to help the dental assistant to understand the handling requirements of the glass-ionomers. As all the materials in this category are essentially the same from a chemical point of view, they can all be discussed under the same headings. There is nothing particularly difficult in their storage, dispensing or mixing; but precision and understanding are a necessary part of good dental assisting, and the following points should always be observed when handling the glass-ionomers.

Figure 8.1

Storage of glass-ionomers

Powders or liquids supplied by different manufacturers or of different Types must never be interchanged. They are all different, and an interchange of components will destroy properties.

Because the glass-ionomers are water-based, they will always be subject to further loss or uptake of water, even from humidity in the air. Therefore both powder and liquid bottles should remain firmly closed at all times (Figure 8.1), and the stoppers should be replaced immediately after dispensing.

With some of the materials available, the liquid supplied is a type of poly(acrylic acid). With others, the poly(acrylic acid) has been dehydrated and is already incorporated in the powder. In this case the liquid will be water or a dilute solution of tartaric acid.

Figure 8.2

- If the liquid being used is poly(acrylic acid), it will be subject to water uptake, and the bottle should remain firmly closed. In addition, it will tend to age and thicken over a period of time. Within 12 months of manufacture, the viscosity may increase to the stage where it flows very slowly and is difficult to dispense accurately. The liquid can be thinned down again to a usable level as follows:
- Immerse the entire bottle of liquid, with the lid on, in water at 75°C (167°F) for 15 minutes. Stand the bottle in a rubber bowl and let water from the hot tap run over it. The bottle will float on the top of the water, but the temperature will be about right (Figure 8.2).

Figure 8.3

Figure 8.4

- Test it at 15 minutes to see that the viscosity has come back to normal.
- Let it cool again before using it.

The liquids should never be stored in the refrigerator; but storage of the powder and the glass mixing slab in the refrigerator will marginally lengthen working time (Figure 8.3). The difference will not be great, but, where the dental office is not air-conditioned, or the average temperature is high, it is worthwhile because it will take the pressure off the clinical handling.

- Make sure that the mixing slab is cool, but not below the dew point, before dispensing the powder.
- Wipe the slab quite dry with a tissue, or there will be a small addition of water to the powder.

Hand dispensing of powder and liquid

If the capsulated varieties of glass-ionomer are not available then hand dispensing must be carried out with great care.

- Read the manufacturer's instructions, which will generally (but not always) suggest that the powder should be fluffed up in the bottle first and a level spoonful extracted and dispensed on to the slab.
- Make sure that the spoon is full and that there is no excess powder on the back of the spoon or along the handle.
- Scrape the top of the spoon over the lip on the bottle, and be prepared to repeat the measure if there are obvious spaces in the powder (Figure 8.4).

If the liquid is poly(acrylic acid), it is difficult to dispense without including an air bubble in the drop, particularly as it becomes more viscous.

- Dispense in two distinct moves.
- Tip the bottle on to its side first, and allow the liquid to run into the spout.
- If the liquid is provided in a translucent bottle, this can be readily observed. If the bottle is opaque, experience will dictate the length of time required.
- Invert completely before dispensing a drop (Figures 8.5 and 8.6). Generally, there will now be a clean drop dispensed, with no air bubble included.
- If the liquid is water or dilute tartaric acid, great care must be taken to dispense only one drop at a time.
- Apply gentle pressure to the bottle or the rubber cuff at the neck of the bottle, since a vigorous squeeze may produce a squirt rather than a drop.

Mixing by hand

Most manufacturers provide a paper pad on which to mix the cement. This is quite satisfactory, provided that the liquid is not left standing

on the pad for longer than one minute. Beyond that time some of the water may soak into the pad and alter the powder–liquid ratio. Use of a glass slab is to be recommended, because it will not affect the water balance. Also, it can be chilled in the refrigerator, and working time can thus be slightly extended (Figure 8.7).

- The principle of mixing is simply to fold the powder into the liquid in the shortest possible time (Figures 8.8–8.10).
- Lightly spread the drop of liquid out over the pad or slab.
- Divide the powder into two parts. Fold in the first half within 10–15 seconds, and then add the second half and incorporate it entirely within the next 15 seconds. Keep the mixing to a small area of the slab only, and do not continue to spatulate beyond 30 seconds.
- Do not spread the mix widely around the slab and do not spatulate heavily. The object is to wet the surface of each particle of glass powder to develop the matrix – not to

Figure 8.5

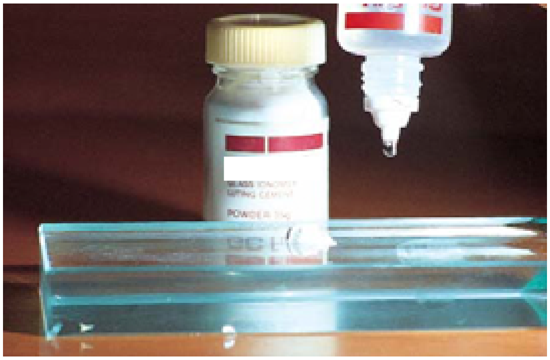


Figure 8.6

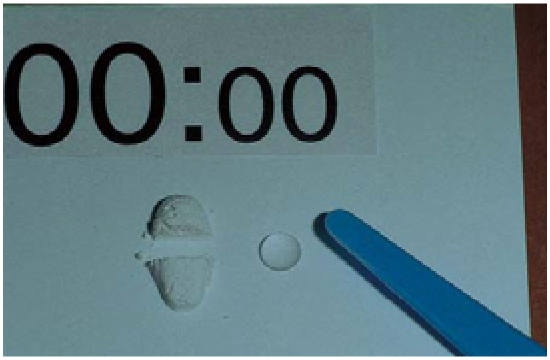


Figure 8.8

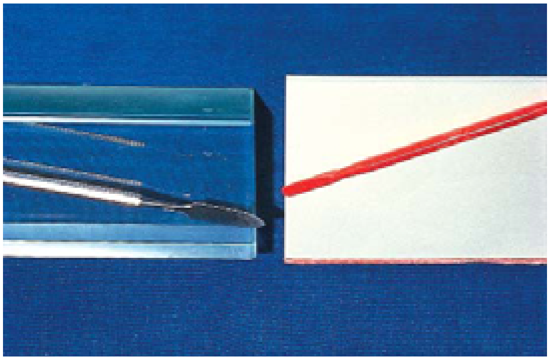


Figure 8.7

Figure 8.9

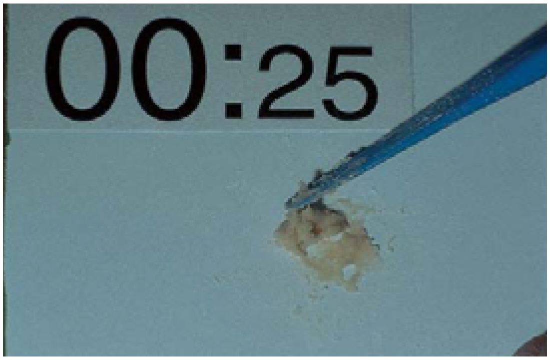


Figure 8.10

Figure 8.11

dissolve the entire particles in the liquid (Figure 1.3).
- Either a steel or a plastic spatula can be used, as long as it is handled correctly.
- Immediately mixing is complete transfer the mixture into a disposable syringe and prepare to place it into the cavity.
- The setting reaction is already under way, and the material should not be handled for any longer than necessary.

Mixing of capsules

- In those materials dispensed in capsules the liquid component is generally a rather viscous poly(acrylic acid). This means that care must be taken in collapsing the capsule to see that all the acid has been squeezed out of its sachet. Follow the manufacturers' instructions in detail.
- If the capsule is activated in a press, apply adequate pressure to the capsule and maintain that pressure for 3 or 4 seconds before releasing and placing the capsule in the machine for mixing (Figure 8.11).
- For some materials it is necessary to give the capsule an extra click in the dispenser first before mixing.
- Note the prescribed mixing time and do not vary it. Use an ultra-high-speed mixing machine, that is, one capable of at least 4000 cycles/min. Machines capable of only 3000 cycles/min or less are not suitable for mixing these materials. It is important to realize that there may be considerable variation between different types of machine, and even some variation within machines of the same brand. This means that results are not necessarily standard (see Box A, page 18).

Loss of gloss test

In view of the variability of mixing machines it is a good idea to find out the optimum mixing time for your machine and then check this occasionally. Placement of the cement after that time may lead to loss of adhesion and reduction of physical properties in the final restoration. To test the machine, make a trial mix. Start the clock at the beginning of mix. Express the mix into a pile on a glass slab and watch it carefully. Although difficult to define, there is a point at which the gloss will have gone entirely from the surface and at the same time the cement will cease to slump back after it is picked up with a small instrument. Normally this point should be reached at about 2 minutes from the start of mix. Vary the time of mixing with your machine to try to standardize the result (see Box A, page 19).

Delivery of the capsule

The moment mixing is complete deliver the capsule ready for placement of the glass-ionomer. Time is at a premium because the material is now setting.

- The recommended time for mixing is usually 10 seconds in a machine capable of 4000 cycles/min.

- Extension beyond this time up to 15 seconds will reduce working time significantly, and is clinically undesirable.
- Reduction of mixing time to 7 seconds may extend working time to about 2.5 minutes, but there is a risk of having unreacted liquid still present (see Box A, page 19).
- Deliver the capsule promptly to the operator. Working time is not long, because of the small temperature rise caused by the high energy of the machine-mixing.

Correct consistency for hand-mixed cements

Type I: luting cements

- Type I luting cements will be mixed at a powder–liquid ratio of about 1.5:1, and will therefore string up approximately 3–4 cm from the slab (Figure 8.12). If the material is to be used as a bond for composite resin or amalgam the powder content will be lower still, so the mix will be very thin.

Type II.1: restorative aesthetic glass-ionomers

- Type II.1, both resin-modified materials and auto cure, restorative aesthetic materials will string only 1 cm off the slab, but must retain a glossy surface.

Type II.2: restorative glass-ionomers

- Type II.2 restorative glass-ionomers will have the same, or a greater, powder–liquid ratio as the Type II.1 restorative aesthetic materials. Therefore they will string up approximately 1 cm off the slab, and must retain a glossy surface. Working time for the hand-mixed variety will be very short (since these cements are generally capsulated, no illustration is shown).

Type III: lining cements

- For lining amalgams, the powder–liquid ratio will be only 1.5:1 for both resin-modified material and auto cure materials, so the cement will string up 3–4 cm off the slab (Figure 8.13).
- For constructing a base for composite resins, the powder–liquid ratio will be 3:1 or greater, so capsulation is recommended. If handmixed, the mixture will string out only 1–1.5 cm, but must retain a glossy surface. Working time will be quite short for the auto cure material, but will be approximately 3.25 minutes for resin-modified material.

Methods of placement

Type I: luting and bonding cements

- Apply with a short, stiff-bristled brush to both the restoration and the tooth (Figures 8.14, 8.15).

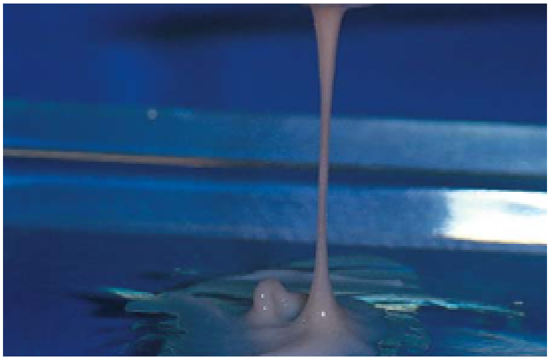


Figure 8.12

Figure 8.13

Figure 8.14

Figure 8.15

Figure 8.16

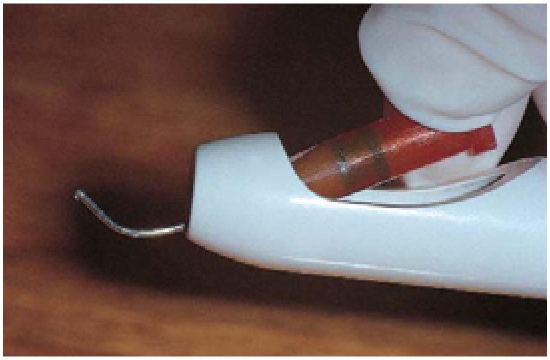


Figure 8.17

Figure 8.18

- For bonding apply a thin coat with a small brush, taking care to avoid puddling in the corners of the cavity.

Type II.1: restorative aesthetic cements

- Apply preferably in a syringe, for positive placement and reduction of porosity. If hand-mixed, transfer into a Centrix-type disposable syringe (Figures 8.16, 8.17).

Type II.2: restorative cements

- Apply in a syringe and tamp into place using a small plastic sponge (Figure 8.18). If hand-mixed, transfer into a Centrix-type disposable syringe.

Type III: lining cements

- To place a lining apply with calcium hydroxide applicator, and allow to flow into place (see Figures 6.2 and 6.3).

Figure 8.19

Figure 8.20

- To place a base or dentine substitute use a capsule or disposable syringe. Tamp into place with a small plastic sponge.

Clean-up procedures

- As soon as the glass-ionomer has been used, and prior to its setting completely, immerse the slab and the spatula in water. It will then clean off quite readily. The longer it is allowed to set, the more difficult it will be to remove (Figures 8.19–8.20).
- If the glass-ionomer has inadvertently been allowed to set on the slab or the instruments, there is no alternative other than to chip it off. Stand it in water for a while first; this will make it easier, but it will still be hard work.

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